MARYLAND

STATE BOARD OF HEALTH.

1887.

THE SANITATION OF CITIES AND TOWNS

AND THE

AGRICULTURAL UTILIZATION OF EXCRETAL MATTERS.

REPORT

ON

Improved Methods of Sewage Disposal

AND

Water Supplies.

BY

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INTRODUCTORY LETTER.

To His Excellency Henry Lloyd,

Governor of Maryland:

Dear Sir—In pursuance of a resolution passed by the State Board of Health on the 19th day of November, 1886, and approved by your Excellency, authorizing me to proceed to Europe to investigate the most recent plans in practical operation for the disposal and utilization of household sewage, especially with reference to the sanitation of Maryland towns, and to report thereon, I herewith present the result of my labors.

Undertaking the investigation with no preconceived notions of my own as to how the problem was to be solved; determined not to be influenced by appeals in favor of any particular scheme, however highly recommended; anxious to receive testimony from all parties, to hear all that could be said and to see all that could be seen, I have been guided not only by a fairly intimate acquaintance with what has been made public during the last ten or fifteen years on the "vexed question" of town sewerage, but by such experience as could be derived from a personal examination of the principal systems in operation in England, France, Germany, Belgium, and Holland.

My views on some points, I am well aware, will not be endorsed by certain sanitarians and engineers in this country, but my conclusions have been formed on what I consider a sound "basis of facts," and, I must believe, a practical working out of the details will show them to be correct.

The principal difficulties which have hitherto environed the subject seem to have arisen from a determination to carry out "foregone conclusions," overlooking the important facts that no one system is universally applicable, and that what may do for one town will not do for another under totally different circumstances.

How then are communities to get out of the diffiiculties in which they are placed? There is a gleam of hope in a direction only recently pointed out, and this is by the adoption of a modification of existing pneumatic systems, such as is described in Chapter XXIV of this report, for large centres of population. And for smaller cities and towns, not able to sustain expenditures proportionate to those of large and wealthy communities; for public institutions, manufactories, private residences, &c., by the use of a very recent invention, described in the Appendix to this report, the main features of which will be gathered from its name, "The Separating and Filtrating Process for Household Sewage." I have carefully studied these devices and can confidently recommend their adoption.

Very Respectfully, Yours,

C. W. CHANCELLOR, M. D.,
Secretary and Executive Officer,
Maryland State Board of Health.

BALTIMORE, May 17th, 1887.

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CHAPTER I.

The Question of Sewage Disposal.

THE whole question of the disposal of town sewage is manifestly one of the greatest difficulty as well as of the greatest importance. Sewage, if left to remain in or near the neighborhood of dwellings or occupied houses, is alike destructive to health and comfort, and if there is anything in the teachings of sanitary science it is an imperative duty of all corporations to get rid of the nuisance at whatever cost. If, in getting rid of the nuisance from a sanitary standpoint, anything is to be made of it from an agricultural point of view, good and well, let it be done. But, in taking a commercial view of the question, it is to be remembered that our farmers are intelligent men, and will not use the material unless it is worth using.

In connection with the supply of manure to agricultural districts, it may be taken as a maxim that the more concentrated it is, the cheaper it will be to the farmer. The transportation of a cheap manure is obviously the same as that of a dear manure, and the tendency is now, very properly, to increase the value in a given quantity of manure. If it is worth fifty dollars per ton, so much the better, provided it contains the same value as could be supplied by fifty dollars' worth of an inferior manure at five dollars per ton.

It is now agreed, that sewage matter of towns, even when largely diluted with water, is a fertilizer of some value, and the point to be settled is whether it can be conveyed to the land at a cost which will render it pecuniarily valuable to the farmer.

On this point Mr. Scott Burn remarks: "If the present "system of tubular house drains, leading to sewers, and these "again to streams and rivers, is to be carried out, then it is "clear that on the one hand we commit a great waste in an "agricultural point of view, by throwing needlessly away that "which, beyond all doubt, contains a comparatively large quan-"tity of fertilizing materials useful for certain crops; and on "the other, we commit a great wrong in a social and sanitary "point of view, by polluting our streams and rivers, poisoning "the very sources from which we obtain the water useful for "household purposes, or making our rivers huge open cesspools, "to flow past or through our towns, sending forth from day "to day the seeds of death and disease."

But even supposing that the present water-carriage method of conveying our town sewage to river outfalls is discontinued, and plans adopted by which the liquid sewage is prevented from entering the river, and dealt with either by pumping it directly on the land, or treated so as to make it part with its fertilizing matter in a solid form, still the present system of drains, necessitating as it does the use of water to make them efficient, presents difficulties which seem inherent in the system; for it is evident the more the population becomes extended, and the farther the present principles—the conveying through the drains "all the refuse which can be estimated to float in water"—are carried out, the greater the quantity of water required, and the greater the decrease in the value of the sewage liquid obtained.

In view of these points, attention has been directed to devising some plan by which both the agricultural and sanitary requirements of the question can be met. Some—and the number is fast increasing—go further and affirm that water-carriage is in principle wrong; that no modification of the practice founded on it will meet the difficulty; that we shall have to begin again—inaugurate another system—at least so far as the excretal result of our population is concerned.

CHAPTER II.

General Principles to be Observed.

THE following may be considered as the general principles upon which the sewerage of towns is to be based:

1. That the proper sewering of a large town depends in a measure on an adequate and regulated supply of water for domestic uses.

2. That two outfalls, independent of each other, should be provided, one for the discharge of the natural or surface waters, and the other for the discharge of the excretal and household sewage.

3. That in order to perfectly drain the surface and sub-soil of a town, so as to free it from dampness, and carry off as quickly as possible the natural waters, where the conditions of

the surface are not such as to accomplish the object without artificial means being provided, a system of permeable drains or sewers should be constructed to receive the surface waters and washings which may be discharged into natural water-courses not used for domestic purposes.

4. That in towns where the surface drainage is good and where outfalls are already provided, by streams or rivers, for the discharge of the natural waters, it is only necessary to make provision for the drainage of the low-lying areas, and to provide separate pipes and outfalls for the excretal and household matters, which should be conveyed as fast as produced to an outlying depot or central station at a convenient and unobjectionable place quite clear of the town.

5. That no correct general views of sewerage can prevail while we continue to regard a stream or river as the natural or suitable trunk sewer for excretal and household wastes, which, according to the state of the river, are spread upon its banks to contaminate the air, or are duly infused into its waters to be afterwards exposed to the same vicious effects and to destroy whatever of life may exist within the water.

6. That, in order to carry off excretal and household wastes without contaminating the atmosphere of the town by the escape of effluvia through the numerous inlets which are necessary for surface drainage, a system of impermeable pipes should be provided, distinct from the permeable drains or sewers, to discharge without intermission and at short intervals into an outfall independent of any river or stream, except for a practically pure effluent.

7. That at the outlet for excretal and household sewage a depot or station should be formed, and works established for converting the sewage matters into an agent or "poudrette" suitable for agricultural and horticultural purposes.

8. That in all towns where an improper system of sewerage works have already been executed, practical operations for a proper system become more difficult, especially if we have to reconcile these with the improved details which correct principles would induce us to prefer.

9. That the saturation of the soil in or near a town by crude sewage matters is a constant concomitant of epidemic diseases, while a proportionate exemption from such maladies has followed the removal of this source of aerial pollution.

10. That the sole purpose of sewers, as distinguished from the drains of a town, should be that of affording a passage for the conveyance of excrementitious matters and household wastes only, all manufactories and trades being required to clean their own waste; not of course to convert it into pure water, but to deprive it of its power to become a nuisance to others when discharged into the public drains or elsewhere.

11. That the conveyance of sewage should be immediate and thorough, every particle committed to the entire ramification of pipes being kept in ceaseless motion until it arrives at the final collecting place; and this desideratum can only be attained in one of three ways: (1) By great declivity of the sewer; (2) By the artificial force of water; (3) By pneumatic pressure or suction, to drive or draw forward the matter.

12. That without one or other of these aids sewers, especially large sewers during dry seasons, will become elongated reservoirs or cesspools in which the refuse matters remain decomposing for days and weeks, sending up the most pernicious gases into the drains and water-closets of houses, and, in the case of large drains, through the ventilating apertures and manholes into the streets of the town.

13. That artificial scouring or flushing of sewers may be regarded as an expensive and troublesome correction of some of the evils occasioned by deficient declivity, and one some-

times attended with mischievous consequences, viz: the forcing up of the sewage into the streets from some of the lower sewers, which become surcharged with flushing water during the process; and furthermore that flushing is inapplicable to any method which proposes to preserve the sewage for agricultural uses.

14. That during the putrefaction of excretal sewage and household wastes, which takes place within from 24 to 48 hours after their discharge, the nitrogen they contain, and which is one of their most useful constituents, is converted into ammonia, which is disengaged, and if this process should take place in the open air, it mingles with the atmosphere in the form of carbonate of ammonia, and leaves the sewage in a much less valuable condition for fertilizing purposes.

15. That the gases engendered by the putrefying matters of sewage, and which too often bring pestilence and death to our homes, would, if retained in the sewage, constitute its most valuable fertilizing properties, and that we should, in order to protect the public health, as well as to convert the fructifying matters into a valuable manure, adopt the best practicable methods of applying the purifying process before these dangerous properties have been developed.

16. That chemistry supplies us with the means by which the most offensive and deleterious properties of the sewage may be suppressed and its useful properties safely retained, and there is no reason why a tank or receptacle in which sewage is collected and stored at the outfall, should be, if properly arranged, in any respect disgusting to the senses or injurious to the health of human beings.

17. That it appears probable such an operation will generally pay its own expenses; but as some such measure is absolutely necessary for the protection of the public health in all centres of population, even though involving expense, it should be the

duty of municipal authorities to carry it out, just as much as arrangements devolving upon them for the removal of street dirt or any other refuse from the town.

18. That the sewage cleared of its solid matter by deodorising and precipitating agents may be used anywhere, and any quantity of it applied to the land without risk of injury to health and without creating as much offensiveness as is experienced from farm-yard and other solid manures applied as top dressings.

19. That the liquid portion of the sewage thus cleared of its solid matters, though pure enough to be emptied into water-courses not appropriated to domestic uses, will still retain considerable value as a manure and may be applied with benefit to the neighboring lands in any reasonable quantity; but that all land upon which it is applied, if not naturally porous, should be artificially drained, since the liquid, if allowed to stagnate in large quantities on the surface, would, as in common irrigation, be likely to engender disease among the neighboring inhabitants, or in cattle exposed to its influence.

20. That public health and economy are the cardinal objects which should be distinctly kept in view in the design and execution of any sewerage system and that these two objects are more certainly and effectually attained when the sewage is carried by pneumatic pressure or suction, for by this means the matter may be collected and dispersed without any detriment to health, and its removal effected at such cost as will be, at least, balanced by converting it readily into a portable manure, whereas, by any plan of water-carriage yet devised, it is rendered quite valueless as a fertilizing agent by the immense dilution necessary, and eventually pollutes water or soil, as it falls into streams or flows upon the surface of the earth.

21. That the cost of a pneumatic system may be reduced to a minimum by skillful arrangements, which seem to have

been attained in the Le Marquand system; but our experience is yet insufficient to enable us to determine this question with that precision which further knowledge will secure, or to estimate *all* the advantages with the exactness necessary for forming a just comparison between the proposed and the present methods. It is quite certain, however, that excrementitious and other household waste matters are far too valuable to be thrown away, and that the question of their conservation and appropriation depends upon the possibilities of an efficient pneumatic system.

22. That as an essential part of any general system of sewerage conducive to the health of the entire population, the connection of every house with the sewers should be commanded and enforced by public authority and carried into immediate effect without favor or evasion; and especially in the construction of all new buildings should this connection be regarded as imperative general orders, sanctioned by the public well-being, and, if necessary, to be obeyed under official superintendence.

Formerly when a town was to be sewered the one question of river or no river was the grand determinal one for the disposal of refuse matters; how to get rid of the animal ordure and kitchen slops within the walls of a town was deemed to be satisfactorily answered provided a stream or river flowed through or near the place, and offered a current or tide to wash away, in boundless wastefulness, those matters which, when properly applied, will endow barren lands with the richest fertility. At the present time the ultimate economy of the art of sewerage comprehends two distinct purposes, whereof the second, viz., the disposal and utilization of the refuse matters, is little less in importance than the first, viz., the discharge of these matters from the dwellings and highways of man.

The accomplishment of the second purpose involves the beneficial appropriation of refuse matters so as to make them actually productive, and to avoid interference with those healthy uses of inland waters for which they are by nature adapted. In illustration of this principle, it will not be amiss to estimate (1), the pernicious effects of discharging these matters upon the surface of the earth, or into streams from whence the supply of water is derived for the several uses of communities; and (2), their value for agricultural purposes.

CHAPTER III.

SEWAGE A FRUITFUL AND DEADLY SOURCE OF CONTAMINATION.

IT is obvious that infection of the soil by decaying organic matters will not only vitiate the subterranean waters, but also the air of dwellings to the extent of impairing health. Independently of the infected volatile products which are evolved in the process of putrefaction, infective germs are sometimes concealed in the excretions, especially the dejections from cholera and typhoid patients.

The accumulation of the refuse matters of every-day life in the neighborhood of human habitations becomes more dangerous in proportion to the quantity accumulated, since the chances of infiltration, with its train of evil consequences, such as vitiated air, polluted soil and contaminated water, are greatly multiplied. Ersmann estimates the poisonous gases eliminated from a ton of excretal sewage—solid and liquid—in 24 hours as follows:

Carbonic Acid	315.0	Liters
Ammonia	149.0	"
Sulphureted Hydrogen	1.2	"
Hydrocarburets	570.0	"

which represents a total weight of 1 per cent.

There is a prevailing impression that the germs of typhoid fever are not communicated through the air we breathe, but are transmitted only by the absorption of the water we drink or the food we eat. A great number of observations, however, have shown this opinion to be erroneous, and it is now known that the disease can be communicated through the medium of infected air.

After studying the various ways by which typhoïd fever may be propagated, Prof. Bouchard of the Faculty of Paris says:

"The transmission of typhoid fever by polluted air rests "upon evidence the most positive. Gielt relates that a man "who had contracted the disease at Ulme returned to his home, "a village in which the malady had not existed for many years, "and the disease soon developed itself in the town. The dejec- "tions of the sick man were thrown on a manure heap; in a "short time thereafter four persons were attainted with the "disease, and a fifth had intestinal catarrh with tumefaction of "the spleen. The dejections of these new cases were buried "under another manure heap, which was opened after nine "months. Two men were employed at this work and one of the "two contracted typhoid fever and died." *

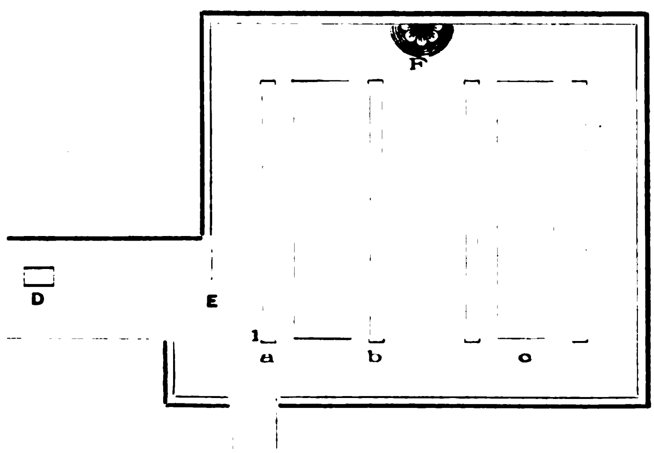
According to Greisinger, the development of typhoid fever depends upon the action of putrid exhalations, particularly such

* Report of the International Medical Congress of Geneva, September, 1877.

as come from filthy privy pits and from excretal matters undergoing putrefactive fermentation in cesspools and sewers. These emanations he regards as "the active elements which play the essential role in epidemics of typhoid fever." *

Laver has communicated the following details of a serious endemic of typhoid fever which occurred in a boys' school attached to a charity institution:

"Of thirty-five pupils twenty-eight contracted the malady. "The first cases, and at the same time the most serious, occurred "among the pupils who occupied the benches *a* and *b*, on the "diagram; and the very first case was that of the pupil who "sat in the seat indicated by the figure 1. The cases observed "among the pupils who sat at the desk *c* were relatively mild."



"All the pupils slept in similar apartments, ate the same "food and, in all respects, were treated alike."

M. Laver was convinced that the fever was caused by emanations proceeding from an open inlet to the sewer, situated in the passage-way marked D. He says: "It will be noticed that "the pupils seated on the benches marked *a* and *b*, who were

* *Traite des Maladies Infectieuses*, page 256.

"the most seriously affected, were directly in the current of air "which came from the sewer-inlet D, through the doorway E "and passed on to the fire F, which at that time was kept burn-"ing all day. Subsequently the opening into the sewer was "closed and the fever did not recur. There was no possibility "of its having been introduced from without, and no case had "existed previously in the institution. The pupils first attacked "had been inmates of the house more than twelve months, and "had not left the premises a single day during the time. The "establishment was situated a little outside the town, but the "sewer communicated with the houses of two or three rich "families, in each of which there had been several cases of "typhoid fever."

Murchison (*Treatise on Typhoid Fever*, 1878, pg. 73) relates the following circumstance: "During the autumn of 1858, an "epidemic of typhoid fever declared itself at Windsor, which "was made the subject of special study by a medical commis-"sion. Four hundred and forty persons were attacked and "thirty-nine died. The opinion of all who were engaged in the "investigation was that the fever was due to emanations from "the sewers, which passed directly into the houses."

In M. Leon Colin's *Study of Typhoid Fever*, (Paris 1878, pg. 109 to 120) he recounts a number of epidemics of typhoid fever, the origin of which the army physicians ascribed to miasmatic emanations from latrines and cesspools located in the barracks or garrison. Many other illustrations might be cited wherein the outbreak of the disease has been traced directly to the poisoned air proceeding from sewers and excretal cesspools.

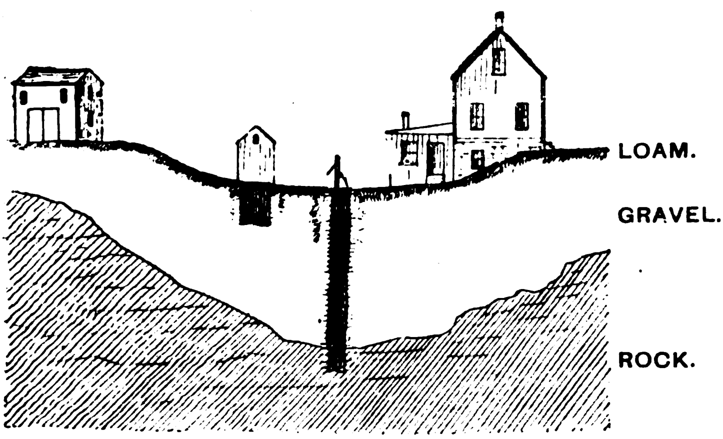
We should hesitate to pronounce as dangerous kitchen slops and other household waste waters, when recently formed, and free from putrescent matters or infectious germs; but Emerich has demonstrated that while such refuse liquids when fresh cause no injurious effects if injected into the circulation of animals, they will occasion disastrous effects if injected after they have remained several days and become decomposed. It not infrequently happens, moreover, that these foul waters contain infectious germs, and the necessity of exercising great care with reference to them is not only important but urgent.

Another evil to be guarded against is the impregnation of the soil by organic wastes which accumulate in the vicinity of inhabited places. It is true we cannot always prevent a certain quantity of household refuse from falling upon and penetrating the soil, but it is nevertheless a duty which we owe to the public health to reduce this source of pollution to a minimum. To a certain extent the earth possesses the power of disinfecting organic matters, and of destroying pathogenic micro-organisms; this has been demonstrated in the case of the *comma bacillus* of Asiatic cholera. But the disinfecting power of the soil, which varies according to its constitution, its permeability to air and water, its condition of humidity, temperature, &c., cannot be relied upon. We find also that the oxydation of organic matter is more active in proportion as the degree of saturation is less, and if the soil should receive more material than it can transform or disinfect, harmless decomposition will be replaced by obnoxious putrefaction.

All who have witnessed excavations made in proximity to filthy cesspools or cess-pits must have observed the black and beslimed condition of the soil, which often emits a disagreeable odor characteristic of the presence of excrementitious matters. This condition is influenced by the porosity or permeability of the soil, and when it exists the saturation does not remain circumscribed, but the foul liquids continue to penetrate in greater abundance until they find an impermeable stratum, or a flowing stream which conveys them perchance into some source of water supply.

Another danger, less apparent but not less formidable, which arises from pollution of the soil by organic matters, is the vitiation of what is known as "ground air." This air, which occupies the interstices of the soil to a depth of several feet, is, especially in the winter when the rooms are warmed, drawn into the apartments and forms part of the ventilation of the rooms, particularly those on the ground floor, which generally contain 10 or 15 per cent. of ground air. One can, therefore, readily understand and appreciate the importance, nay the necessity of preserving the soil near dwelling houses in a pure and uncontaminated condition, for, as is the soil near a dwelling, so will be the air within.

It is manifest that where the disposal of excrementitious matters are not made with proper care, and where the water supply for domestic purposes is drawn from superficial wells, the depth of which seldom reaches more than 20 or 30 feet and rarely exceeds 50 feet, there is great danger of contamination, since the filtering bed through which the refuse liquids percolate and are carried in their course by meteoric waters are insufficient to transform or disinfect all the poisonous organic matters which they contain.



The above diagram illustrates how a well may be contaminated from surface drainage and soakage. Five cases of typhoid fever occurred in the family living in the house, and seven more among other persons using water from the same well.

This condition, important in a sanitary point of view, is characterized by the presence in the water of nitrates, nitrites, ammonia, chlorine, potash and organic matters notably in excess of those found in water drawn from unpolluted wells, or wells situated remotely from any source of pollution. It is quite well known to all who have paid attention to such matters, that water may be entirely limpid and tasteless and yet contain the same organic matters which are found in the most offensive liquid sewage.

It appears, moreover, from the evidence of scientific research, as well as from reasoning by analogy, that water may be contaminated by being mixed not only with the organic matter of sewage, but also by passing over or coming in contact with the polluted soil of graveyards, decomposing matters of cesspools and privies, or by the organic matter derived from the decay of any animal or vegetable organisms. But the most dangerous sources of contaminated water are undoubtedly the wells, springs, streams or rivers from which water is used for household purposes, and into which more or less excretal sewage has passed. Numerous cases in proof of this could be cited, but it is only necessary to give the following, which is indicative of general results in similar cases:

Mr. Burns relates that in a certain town of Scotland there was a severe outbreak of dysentery and typhoid fever. A physician called to attend some of the cases, set to work to find out the cause. On inquiry as to the water supply, he was directed to a spring on low ground in the midst of the settlement, so situated as to receive the drainage from a cesspool. The water was pure and sparkling to the sight and taste, and was loudly praised by those who used it. A quantity put in a bottle and allowed to stand a few hours, threw down a thick sediment of most offensive matter, which, on being tested, was found to be as purely excrementitious as if it had been taken from a privy. The people ceased to use this water, and the epidemic disappeared at once.

In a village of New York typhoid fever broke out and prevailed with great violence in a certain locality. Search was made for the cause by the attending physician, but in vain. An appeal was made to the health authorities, and an expert officer examined the history of the outbreak and predicted that a certain hydrant which supplied the victims with drinking water communicated at some point with house drains or the street sewer. The water-pipe was examined, and at a distance from the hydrant a house drain was found leading into it at a point where they traversed each other. The repair of these pipes was the cure of the epidemic.

In a farmhouse in Massachusetts, situated in an interior township famous for healthfulness and the beauty of its scenery, typhoid fever broke out in a violent form. Of eight members five perished and one was seriously ill. The house was situated on an elevation, and all its surroundings were admirably arranged for health. One could readily believe the statement that "there had not been a case of sickness in the house for twelve years." The following is a history of the sickness: "A few weeks before the disease appeared, the pump in the "well broke, and the farmer being pressed with work, neglected "to have it repaired. Meantime the servants brought water "from a spring at the foot of the hill, which soon became low, "owing to a drought. Resort was then had to a small brook, "and from this source the family were supplied with water for "two weeks. This stream, higher up, ran through several farm "yards, and received the surface drainage. The first symptoms "of poison by this water were slight nausea and a mild diarrhœa.

" After several days typhoid fever in its worst form was ushered "in. Of the entire family, but two escaped an attack, and " they did not use the water. An examination of this water " revealed a sediment of excretal matters."

At Pittsfield, Massachusetts, typhoid fever suddenly broke out in a large boarding school for young ladies. The water was found to be contaminated with sewage, owing to leakage from the cesspool. A similar occurrence took place some years ago at Princeton College, New Jersey.

At Edgewood, on Staten Island, Prof. Chandler relates that the inmates of a small block of houses were affected with typhoid fever, several deaths occurring. On making investigation, it was found that a neighbor through whose land the underground drain passed had taken the liberty of closing up the drain, thus sending its contents back upon this block of houses, con-
tims taminating the wells, and murdering the unfortunate vic-
with sewage poison.

The process of filtration through the soil, which water derived from subterranean sources undergoes, tends to separate the organic impurities, animal and vegetable, but this process is often palpably insufficient to secure the requisite purity. The topographical and geological character of the site of the town, and of the soil and sub-strata, are also to be taken into consideration.

In speaking of the bored wells on Manhattan Island, numbering about sixty or seventy, and varying in depth from twenty-six to two thousand feet, eighteen being more than five hundred feet deep, Prof. C. F. Chandler states that the water from such wells can never be free from danger, if drank before being boiled. "The geological formation," says Prof. Chandler, "renders it impossible for water to come in from beyond the "limits of the island, except possibly in one locality, for a short "distance south of Harlem river. It is only filtered surface "water, and however clear it may be, it is always in danger of "containing disease germs which cannot be filtered out by the "soil." Prof. Chandler also declares, in a paper on "The Sanitary Chemistry of Water," published in the reports of the American Public Health Association, that "many diseases of the most "fatal character are now traced to the use of water poisoned "with the soakage from soils charged with sewage and excre-"mental matters."

Dr. Macadam, a distinguished chemist of Edinburgh, Scotland, who has paid great attention to the water question, states that, "the line must be distinctly drawn between non-putrescent "organic matter and that which is putrescent. Impregnations "from sewage form the most dreaded contamination, and yield "waters which though clear and sparkling, and cooling and "refreshing, are yet most unwholesome and deadly."

Dr. Frankland maintains that water once contaminated with sewage matter, even if purified subsequently by filtration in the most perfect way attainable, if not positively dangerous, is still unsafe to be used. "There are animal organisms existing "in sewage matter so minute as not to be seen by the unaided "eye; and we have reason to believe that they even exist out-"side the range of microscopic vision and possess powers "antagonistic to human life. By their minuteness they defy "filtration, and such is their tenacity to life that they are said "even to outlive the process of boiling."

The futility of simple filtration has been clearly established by the experiments of Dr. Frankland, which he thus describes: "One volume of the rice-water evacuations of a "cholera patient was mixed with 500 volumes of distilled water "and the mixture passed through filtering paper. Before the "filtration the liquid was opalescent, and so it remained after-"wards. In this state 100,000 parts of the filtered liquid, when "submitted to the action of potassic permanganate, required

".0430 part of oxygen for the oxidation of the organic matter "contained therein. The average amount of oxygen required "to oxidize the organic matter contained in 100,000 parts of fil- "tered Thames water, as supplied to the metropolis, is .0724 part. "Thus, according to the potassic permanganate test, the diluted "rice-water was far purer as regards organic matter than the "water ordinarily drank by the inhabitants of London. In "fact," says Dr. Frankland, "it may be safely asserted that the "addition of cholera rice-water to the water of the Thames, in "the proportion of 1 to 1,000, would not materially affect the "result of a chemical analysis of the water. The filtered rice- "water liquid was next passed rapidly through animal charcoal. "The opalescence was thereby further diminished, but not "entirely removed. The organic matter still remaining in "100,000 parts required only .0103 part of oxygen for its oxida- "tion." Dr. Frankland sums up by saying: "The foregoing "experiments show, first, that the water may be seriously con- "taminated with choleraic matter, without the presence of the "latter being indicated by chemical analysis; and, secondly, that "water so contaminated is not completely deprived of this "impurity either by filtration or passage through animal char- "coal."

Experiments by Prof. Thiersch and Dr. Saunderson show that paper saturated in cholera flux and dried, when eaten will produce the disease in a transmissible form in mice. "The fresh "flux the first day after exposure in the air is almost inert, on "the second day it grows more active, on the third it is at its "maximum of activity, is less and less active on the fourth and "fifth, and becomes inert on the sixth day of transformation. "Of 148 mice experimented on, 95 showed no symptoms, 53 "were affected, and of the latter 31 died. It is remarkable that "on a second occasion, when the thermometer had fallen from "56° to 49°, the experiments failed. One circumstance which "increases the danger is the law observed by cholera, in common "with other zymotic diseases, whereby the mildest type is "capable of communicating the disease in its most malignant "form. Thus the most virulent cholera matter is producible "from patients who are seemingly only attacked with diarrhœa. "Experience also shows that water poisoned by sewage is "capable of propagating cholera, even though the water be "boiled and drank in the form of tea."

Cholera flux is represented to be of low specific gravity, and sinks very slowly in water. Dr. Hassall describes the deposit, when seen under the microscope, as consisting of "innumerable "mucous corpuscles, globules of oil, and myriads of vibriones." Pacani has found that the germs of vibriones are less than the 25,000th of an inch in diameter; so that if heaped in a mass, there would be as many as 15,625,000,000,000 germs in a cubic inch. "Allowing for interspaces," says Dr. Farr, "it is evident "that a cubic inch might hold millions of cholera particles, and "one cholera patient might disseminate in water millions of "zymotic molecules. The infective power of the cholera liquid "grows and declines by a law of its own; and the water which "on one day is poisonous, may a few days afterwards be "harmless." The occurrence of the vegetable species and animalculae is, says Dr. Hassall, "an infallible proof of the pres-"ence of organic impurity in its worst stage,—that is, in the "act of putrid decomposition, or in the course towards this "consummation."

Such is the nature of the influence which may be said to threaten the water supply of some of our Maryland towns. The analysis of waters from several of the wells of Towsontown made by Prof. Tonry for the State Board of Health, during the existence of typhoid fever in that place, showed the presence of nitrates and a considerable amount of organic matter, and we cannot be assured that animal organizations of a dangerous type will not sometimes accompany these compounds. And what is true of the water supply in Towsontown is equally true of most of the towns and villages in the State. Certainly, taking all things into consideration, it appears to be unmistakably a wrong thing to draw the water for house consumption from wells or any other source of supply into which sewage matters are passed. Clearly, the utmost care ought to be taken to exclude impure fluids and other offensive matters from every water supply, and in most of our towns this can only be effected by providing a proper system of sewage disposal. "For health's "sake, without consideration of commercial profit, sewage and "excreta should be got rid of at any cost."

CHAPTER IV.

Reduction of Mortality Following the Introduction of Sewers.

THE great importance of avoiding all sources of unwholesome and offensive effluvia, and of preserving the foundations of buildings, and the substrata of the soil of a town in a dry and clean condition, creates a severe necessity for relinquishing cesspools and all receptacles for sewage within or connected with buildings, except those to which the material is conducted for purposes of collection and treatment.

The advantages to be derived, in a sanitary point of view, and the great reduction in the annual mortality of towns from the construction of an efficient system of sewers, has been strikingly set forth by Capt. Douglas Galton, of the Royal Engineers, in an address before the Sanitary Institute of Great Britain, from which the following extracts are taken:

"It may be accepted as certain that in every case where "the sewage of towns has been devised on sound principles, and "where the works have been carried on under intelligent super- "vision, a largely reduced death-rate has invariably followed. "The records of Newcastle afford evidence of this fact. The "quinquennial period beginning in 1868 showed a death-rate of "27.6; the quinquennial period ending in 1881 showed a death- "rate of 23.0; whilst the death-rate of 1881 was only 21.7."

"At the recent Sanitary Congress at Vienna, some remark- "able results of the effects of the sewerage of certain German "towns were given, which are very striking."

"Munich is the residence of one of the ablest sanitarians of "Europe, Dr. Pettenkofer. His admirable illustrations of the "effect of the impurities which were accumulated in porous "cesspits upon the air of the town, and the death-rate of the "population, form a text-book of sanitary knowledge."

"At Munich, the enteric (typhoid) fever mortality *per* "100,000 *of inhabitants* per quinquennial periods was as under:

1854 to 1859, when there were absolutely no regulations for keeping the soil clean	24.2
1860 to 1865, when reforms were begun by cementing the sides and bottoms of the porous cesspits	16.8
1866 to 1873, when there was partial sewerage	13.3
1876 to 1880, when the sewerage was complete	8.7

"Similarly at Frankfort-on-Main, the deaths from enteric "fever *per* 10,000 were:

1854 to 1859, when there was no sewerage	8.7
1875 to 1887, when the sewerage was complete,	2.4

"At Dantzic, the figures present some striking character- "istics; the deaths from enteric fever *per* 100,000 *living* was as "follows:

1865 to 1869, when there was no sewerage and no proper water supply	108
1871 to 1875, after the introduction of water supply	90
1876 to 1880, after the introduction of sewers	18

"Hamburg has been drained by Mr. Lindley, and he has "stated that in his plans he carefully followed the principles "laid down by Mr. Chadwick. In that town, the deaths from "enteric fever *per* 1,000 of total population were:

From 1838 to 1844, before the commencement of the construction of any sewerage works	48.5
From 1871 to 1880, after the completion of the sewerage works..	13.3

"During the time that the works were in progress, viz: from "1872 to 1874, the mortality from enteric fever *per* 10,000 *living* "was:

In the unsewered districts	40.0
In the districts for the most part sewered	32.0
And in the fully sewered districts	26.8

Dr. Buchanan, Medical Officer of the Privy Council of England, in his Ninth Report has shown the marked improvement to health which followed the introduction of drainage, sewerage and water supplies, in twenty-five cities and towns, with an aggregate population of 593,736 persons. The average of the death-rates per 10,000 for the different places decreased as follows:

Mortality from all Causes	from	247.55	to	219.87
" " Typhoid Fever	"	13.34	"	7.8
" " Diarrhœa	"	8.45	"	7.66
" " Pulmonary Consumption	"	34.44	"	27.3
" Among Children under 1 year old	"	55.65	"	50.00

In some of these towns it was clearly demonstrated that improperly constructed sewers had increased the death-rate, by exposing people to the direct effect of deleterious gases.

These results illustrate the effects of purifying the air of towns by the rapid abstraction of refuse matter, so as to prevent it from remaining and putrefying in and upon the ground. These figures show a reduction in the death-rate of the above towns from typhoid fever alone of fully 24 per cent., and it is fair to presume that diphtheria and other zymotic miasmatic fevers would be similarly affected.

It may, therefore, be estimated that in the city of Baltimore (where there are, according to the last Report of the Health Department, 1,780 deaths annually from such diseases), about 500 persons who now die of these diseases would be saved from death every year if the city were properly sewered; and if twelve cases of serious, but not fatal illness be reckoned for every death, it follows that about 6,000 persons would be saved from a sick-bed through the influence of this sanitary measure alone, while the saving to the body politic may be estimated in figures as follows:

500 funerals at an average cost of $30 each	$ 15,000
6,000 cases of sickness at an average cost of $15 in each case for medical treatment and other expenses incident to sickness	90,000
Loss of time, averaging 10 days in each case of sickness, at $2.50 per day per person	150,000
Total annual loss	$255,000

Which sum capitalized at 5 per cent. would amount to more than $4,000,000, or a sum quite equal to the cost of constructing an efficient system of sewers.

Concerning the benefits derived in England, for the decennial period 1870–1880, from sanitary measures the Local Government Board thus speaks:

"On the demonstrations of various model instances, it may "be held that the reduction of the general death-rate (three-"eighths of the entire reduction being in 'fever') by four and "one half per cent., as reported, satisfactory as this is, cannot "be considered more than one-third of the results obtainable

" by advanced sanitary administrations and further sanitary " works. The pain and misery and the social disorder occa- " sioned by excessive sickness and premature mortality are " greatly beyond pecuniary estimation."

"Among the causes," says Mr. Gray, " which have operated " in England to produce these remarkable results may be men- " tioned the construction of more perfect systems of sewerage " and house drainage, the gradual disuse of cesspools and wells, " the introduction of more copious water supplies, the more " efficient seweraging of towns, the sanitary inspection of " dwellings, and the purification and utilization of sewage."

Although a great deal has been done in Maryland to arouse the public from their apathy, there is reason to believe that much indifference still exists, even in the principal cities of the State, upon the subject of sanitary reform, and that the people are too much inclined to overlook the evils which surround them. How long the problem of sewering the city of Baltimore, the solution of which is not by any means overwhelming, will be permitted to rest unattacked may possibly only be determined by the occurrence in the future of an epidemic decimation, giving the neccessary stimulus to more advanced metropolitan sanitary legislation, thereby removing what now exists as a blot upon the cleanliness of one of the largest and most beautiful cities in the country.

CHAPTER V.

Composition and Manurial Value of Sewage.

IT is quite impossible to estimate with precision the amount of excretal matter which is produced daily by a mixed population, composed of persons of all ages and conditions. The estimate to be accurate should be made for each particular case, since the amount will necessarily vary with age and the conditions of life, viz., the amount of food, the consumption of water, &c We can, therefore, only take as a basis of calculation the average of different authors.

The quantity of solid excreta yielded per day by each individual, taking all classes and all ages together, is estimated by Parks at 75 grammes (2½ oz.) of fæces and 1,200 grammes (40 oz.) of urine per day. Frankland concurs with Parks as to the amount of urine, but he estimates the quantity of fæcal matter at 90 grammes (3 oz.) Pettenkofer fixes the amount of solid matter at 93 grammes ($3\frac{1}{10}$ oz.) and the urine at 1,172 grammes ($39\frac{2}{3}$ oz.) per day per person. Averaging the figures of the three above authorities we find that the fæces amount to $2\frac{2}{3}$ oz., and the urine to 39¾ oz. per day per person, which may be regarded as correct. Pettenkofer further estimates that house and kitchen wastes will average 223 grammes (7½ oz.) per head per day, or about 165 pounds per person per year. The household waters he fixes at 5 gallons per day, or in round numbers at about 2,000 gallons per person per year.

In America, where water is more lavishly used, these figures may be doubled if not quadrupled.

A special commission of sanitary experts, consisting of Messrs. Royers, Devaugh and Putzeys, have recently made a report to the Royal Society of Public Medicine of Belgium on the removal of excrementitious matters from centres of population, in which it is stated that the refuse household materials, liquid and solid, which has to be removed from habitations, represents per head and per year a total of 7.852 kilograms, or about 17,275 pounds, into which there enters:

Solid fæcal matter	0.45 per cent.
Urine	5.45 " "
Products of house waste	1.15 " "
Refuse waters	92.97 " "

The Commission further estimates that for each 1,000 of population there will be:

34	cubic	metres (tons)	of	fæcal matter.
428	"	"	"	urine.
7.300	"	"	"	soiled waters.
90	"	"	"	house waste.

It is quite impossible, says the Report, to estimate the volume of industrial waters, since the quantity used in each instance varies with the nature of the industry.

Industrial wastes, however, are not to be neglected; on the contrary, it is very desirable, in a sanitary point of view, that their proper disposal be provided for. Certain industries, such as slaughter-houses, tanneries, manufactories of cloths and chemicals, sugar refineries, glue factories, rendering and dyeing establishments, &c., produce wastes which are particularly objectionable, since they readily pass into a state of fermentation and putrefaction, and become a fruitful source of danger to public health.

The following table, taken from the Report of the Rivers Pollution Commission of England, gives the average composition of sewerage in parts per 100,000:

Description.	Solids in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
Water Closet—										
Towns	72.2	4.696	2.205	6.703	.003	7.728	10.66	24.18	20.51	44.69
Middens—										
Towns	82.4	4.181	1.975	5.435	.000	6.451	11.54	17.81	21.30	39.11

Messrs. Schlœsing and Durand-Claye, after ten years of careful investigation, furnish the following analysis, per cubic metre (ton) of sewage water, taken from the outfall sewers of Paris:

Nitrogen	45 grms.	723 grms.	2908 grms.
Other volatile or combustible matters (principally organic)	678		
Phosphoric acid	19	2185	
Potash	37		
Lime	401		
Soda	85		
Magnesia	22		
Insoluble matters (principally selicious)	728		
Mineral matters	893		

The municipal engineers of Paris have ascertained that from 250,000 to 260,000 cubic metres (tons) of this impure water are emptied daily into the Seine from the "collecteurs" or intercepting sewers, and this amount constitutes about 70 per cent. of the daily water supply of the city, the remaining 30 per cent. being disposed of by evaporation. Two-thirds of the matters contained in these sewer waters, *i. e.*, 1,940 grammes of the 2,908 are solid matters, and formed for the most part of sand, or debris washed from the streets. The dissolved materials, *i. e.*, 968 grammes of the 2,908, contain one-half of all the nitrogen and organic matters, and all the potash.

The sewer waters of London have less solid material, but are richer in nitrogen than those of Paris. According to the analysis of Frankland they contain on an average, *per cubic metre*, 643 grammes of solid material (three times less than the sewer waters of Paris) and 64 grammes of dissolved material. These elements are given as follows:

Nitrogen, dissolved: organic, 25 grms.; as ammonia, 46	71 grms.	80 grms.	1288 grms.
Nitrogen, contained in the solids	9		
Organic carbon	44	1208	
Chlorine	104		
Other dissolved matters	426		
Other matters in suspension	634		

The analysis of mixed gases obtained from sewer mud by M. Charles Girard, Director of the Laboratory of the Prefect of Police of Paris, gives the following result:

Sulphuretted hydrogen	0.96
Carbonic acid	9.60
Oxygen	0.96
Protocarbonate of hydrogen and nitrogen	88.40
Total	100.00

But if we examine the chemical composition of excrementitious matters alone we shall find, according to the Report of the Belgian Commission, that the fæces contain about 75 per cent. of water, 1.2 to 2 per cent. of nitrogen and 3.25 to 3.75 of combustible matters, which furnish 1.6 per cent. of phosphoric acid, 0.29 per cent. of potash and 1.4 per cent. of nitrogen. The last three substances merit especial attention on account of their great importance in agriculture.

The composition of urine is more variable than that of the fæces:—The proportion of water varies between 93.3 and 96 per cent.; that of nitrogen between 1.2 and 2 6 according to the food; the quantity of phosphoric acid and of potash are each 0.2 per cent.

It appears from the foregoing figures that one person will, on an average, excrete annually with the fæces from 1 to 1½ pounds of nitrogen, and with the urine from 10 to 12 pounds; 13 ounces of phosphoric acid are excreted with the fæces, and 2 pounds with the urine of each person annually; and if we consider that the fermentable principle of excrementitious matters resides principally in the nitrogenous substances which they contain, and that it is from this source more particularly that the pollution of soil, air and water occurs, we can readily understand that the urine is in every respect of greater importance than the fæces. This fact being known, attention to conserving the urine both as an economical and health measure should not be lost sight of.

The value of manures as promoters of vegetation is known to result from their possessing the essential element, nitrogen, in the form of ammonia, with the subordinate properties of alkalies, phosphates and sulphates. Now, according to the figures of the Belgian Commission, the quantity of nitrogen contained in the excrements of each person during one year is about 16 pounds, including about 3 pounds of phosphoric acid, and this quantity is sufficient for the supply of 800 pounds of wheat, rye, or oats, and more than is necessary to add to an acre of land, in order to obtain, with the assistance of the nitrogen absorbed from the atmosphere, the richest crops every year. Making reasonable allowance for the reduced quantity produced by children, we shall be safe in assuming that the nitrogen thus resulting from any amount of population is equal to the supply required for affording 2 pounds of bread per diem for every one of its members. Or assuming an average of 600 pounds of wheat to be manured by each individual of the population of Baltimore, and estimating this at 400,000, the manure thus produced would be sufficient to supply a growth of wheat of a total weight of 240,000,000 pounds.

Other authorities variously estimate the manurial value of the excreta voided daily by 1,000 persons, in their natural condition, at from $5 to $10. This is the theoretical side of the question, for its value is dependent upon circumstances more or less numerous. If diluted with the enormous quantity of water with which town sewage is usually diluted in the water carriage sewers, instead of finding that we have a value of $10 or $20 per ton, we will have a value of only a few cents per ton. Again, the manurial value of sewage not only depends upon what, as a fertilizing substance, it is as compared with other fertilizing substances, but upon the facility and costlessness with which it may be transported. We have already stated that the more concentrated a manure is, the more valuable it is, not merely because the whole of it, or nearly the whole of it, goes to the plant's nourishment—no extraneous and valueless matter being mixed up with it—but because of the transport from place to place. Valuable as we all admit farm-yard manure to be, there is a limit beyond which it would cease to be valuable at all, inasmuch as the cost of its transportation would be worth more than its fertilizing value. Not only is the question of relative bulk to be taken into account, but we must also consider whether we can use the bulky manure when and where we require it. The more bulky a manure is, the less manageable it will be, and the less valuable it will be in a practical point of view. Considerations such as these are eminently practical, and will always affect the sewerage question; but it is not possible, under the water carriage system, to lessen the bulk of the resulting sewage to a great extent, if indeed to any extent.

"The question of bulk," says an eminent authority, "is one "to which attention must be paid if we wish to come to a cor- "rect conclusion as to what chances there are of sewage being "used agriculturally, in all cases where made, that is, in the "neighborhood of towns. The fact that after the lapse of so "many years, so few towns have managed to get rid of their "sewage in a satisfactory manner, shows, beyond any cavil, that "there are difficulties in the way of using sewage. And the "difficulty is—or rather we should say the difficulties are—enor-"mously increased by the local circumstances of many towns, "and the character of the land there met with, judged from "an agricultural point of view." This authority further says: "Land cannot be obtained of sufficient extent in the "neighborhood of towns in which the sewage is produced for "irrigation purposes; and this may safely be accepted as the "rule, when we consider that one acre is required for every "twenty or twenty-five individuals of the population. The "land must, moreover, be of a certain quality, to give the best "results; and locally, so far as its surface is concerned, arranged "in a certain way before the best results of the application can "be secured. With regard to this point there is, or rather will "be, if the sewage of large towns is to be used for irrigation, an "almost insuperable difficulty in getting the requisite quan-"tity and the proper quality of land for the utilization of the "enormous quantities produced by the present system of town "sanitary arrangements," *whereby the excretal matters are discharged into the same channels with the waste waters and all other matters from the surface of the streets.*

We have seen that the average quantity of excretal matter, solid and liquid, passed by one person in twenty-four hours amounts to forty-three ounces. Now the city of Baltimore, with a population of 400,000, has up to the present time allowed to go to waste, in round numbers, 200,000 tons of excretal matter annually, which could be converted into a valuable fertilizer. And as the population of the State of Maryland is about one million, there could be preserved upwards of 500,000 tons of excreta which is now allowed to go to waste, and which, if it were properly treated, would produce at least 125,000 tons of a valuable fertilizer, worth in the aggregate more than $3,000,000. In addition to this great advantage to the agricultural interests of the State, the cities, towns and villages would be relieved of excretal matter, which is now a problem of so much difficulty.

The value of the fertilizing constituents in human excretions are fixed by Goessman as follows:

Nitrogen	15 cents per pound.		
Soluble Phosphoric Acid	12	"	"
Reverted Phosphoric Acid	9	"	"
Potassium Oxide	7	"	"

In Germany the nitrogen is estimated in the following manner:

Total Nitrogen, 7.24 per cent. { 4.49 per cent. as Ammonia.
2.75 per cent. as Organic Combination.

VALUE.

Nitrogen as Ammonia	24 cents per pound.		
" " Organic Combinations	15	"	"

CHAPTER VI.

MODES OF DEALING WITH SEWAGE. CESSPOOLS AND OPEN PRIVIES.

THE refuse matters to be discharged from towns and buildings, consisting of the disintegrated material of streets; of superfluous rain water; of excrementitious and household matters, solid and liquid; of the waste products of combustion; of the refuse of animal and vegetable substances, require arrangements of different kinds to be provided with regard to the purposes to which these matters may be usefully applied.

In sewerage, as in many other subjects, controversy has frequently been found to be excited upon those very details of the art which appear to be most simple and the most readily deducible from observation, while the proper ground for discussion, in which it is really urgently needed, in order to determine general principles and mark out leading rules, has been left nearly or quite unoccupied. Thus the forms, sizes and thicknesses of sewers have received the most elaborate investigation, and provoked an expression of the most widely different opinions, while the great question of the most healthful and economical disposal of the refuse of towns have, until lately, remained unsought and unasked. "Misled by an instinctive adoption of "obsolete plans," says Mr. Drysdale, "we have been content to "build sewers, patch upon patch,—add length to length of slug-"gish sewer or practical cesspool, without any principle of "arrangement according to which the entire system should be "laid out, in order, it may be, to maintain ancient outfalls."

Reference has already been made to the connection between defective sewerage, or no sewerage at all, and the propagation of disease. It is now universally admitted that the exhalations arising from the decaying putridity of deficiently arranged and constructed cesspools and open privies are strongly inducive of disease. Indeed the immediate and direct cause of zymotic disease may be said to be the poison generated by the decomposition of animal and vegetable matters. The experience of every medical man goes to prove that a badly cleansed and drained district is always an unhealthy one. A competent witness remarks that, "in addition to a general derangement of health, "and an unusual liability to disease, there is one particular class "of disease which is always to be found in neglected places, viz., "the class of contagious disorders." History teaches us that pestilence has always haunted the scenes of filth. The plague, the black death, the cholera, have all made these places their favorite resorts; and typhoid fever and diphtheria, our modern pestilences, form no exception to the rule.

It may be laid down as a great leading principle in the drainage of towns and houses, that *no system for getting rid of human excreta and household waste matters, solid and liquid, can be considered satisfactory which does not provide against vitiation of air, contamination of soil and pollution of drinking water, the most perfect method being that which will provide for the complete, immediate and rapid removal of all waste matters susceptible of decomposition.*

The term "drainage" and "sewerage" are distinct subjects, though, unfortunately, they have come to be used as if they were the same. At one time it was not so. Town drainage, when first introduced, was intended, as it was practically carried out, only as a means of carrying off from the neighborhood of houses the refuse waters of their domestic operations, and for the removal of rain or surface water, and the refuse of manufactories. So completely distinct were they considered from the system of cesspools, that in most places entrance into them from the cesspool was prohibited under a positive penalty; and further, so distinct were they from any system of sewerage that all excretal matters were forbidden under a penalty to be conducted or thrown into them. The result was, that as the "water closet" became more and more used, and the supply of water to towns was gradually and greatly increased, the "cesspool" system became a greater difficulty than ever, and the evils,—in the form of still more completely saturated soils, polluted wells and foundations, and cellars flooded with stagnant and offensive fluids,—became at last so notorious that a new system became positively imperative, and in place of connections between the water-closets and the storm water drains being rendered a matter of impossility or difficulty the connection was in some instances made imperative. The drains were no longer looked upon as simply a means for conveying the slop water of houses and the surface water of streets, but were made to convey, not only these, but also the excrementitious matter from houses. Formerly they were permeable, not only admitting water draining from the surrounding soil to enter into them, but they acted in the converse way, allowing their contents to pass from their interior and permeate the soil surrounding them. All this was changed. From permeable they were changed to impermeable, so that they were absolutely water-tight, as far as practically possible, in order to retain within their interior the matters which they conveyed, and to prevent as much as possible their passing out to pollute the soil by which they were surrounded.

It will thus be seen that the two systems of old town drains and the new town sewers were specially distinct. In many towns, even in parts of London and Paris, the old drains still remain, being made to serve the purpose of excretal sewers, for which they are quite unfitted, giving rise to evils of a character perhaps less obvious and open to inspection, but not less dangerous than those arising from the old cesspool system. These drains or so-called sewers are but elongated cesspools, and creating, as they must create, a vast amount of foul air in the aggregate, they are certain to act in a way even more dangerous than the old cesspits, for the latter being placed outside the house any foul exhalations from it have the chance of being diffused in the air, or blown away from the neighborhood of the house by favorable winds; whereas, the latter are placed in direct communication with the interior of dwellings by the house soil pipe, so that the foul gases are delivered where they are most dangerous, and must necessarily pass through the house before they escape to the external atmosphere,—if they escape at all. Hence arose the necessity for introducing some means of preventing the gases created in the sewers from passing into the interior of the houses with which they are directly connected. This has been attempted to be effected by what are called "water seals," or in other words "stench traps." By this arrangement the poisonous gases from the interior of the drain are *supposed* to be prevented from passing through the trap, so long as it is completely filled with water.

In the use of the "trap," the gases are "supposed" to be prevented from passing from the drains to the house, but this is not the case, for in many instances the "trap" does not act as such. Its efficiency, at all events, is very doubtful in the generality of cases, since the body of water in the trap or the weight of the "water seal" may be altogether incapable of resisting the pressure of the gases acting upon the drain side of the trap, in which case the gases are simply forced through the trap and pass at once into the house. Nor is this result prevented by extending the soil pipe up to or above the roof level, for often the density of the atmosphere is such that the gases, instead of passing out through the ventilating pipe, will force the "seal" and pass into the house.

In addition, moreover, to the ease with which, under certain circumstances, the gases from the drains and sewers are forced through the small columns of water in the trap, this in certain forms is frequently evaporated, or syphoned, leaving the trap dry, and, of course, in this condition, it is only a trap in name, experience having shown that traps are, in a great many instances, wholly inoperative. A very simple proof of this is open to the inspection of all. Sewage gases are known to contain, as one constituent, sulphureted hydrogen gas; this discolors white lead exposed to its action. Now if the under side of the cover or lid of the water-closet, for example, be painted, and this be closed, the paint becomes, in course of time, quite black; this is caused by the sewage gases being forced through the trap and coming in contact with the paint; if it were not so, the paint would not, ordinarily, become discolored.

In view of the fact that, in a very large number of cases, water-closets and their "traps," as well as the connecting pipes, are defective, and allow readily the escape of gases from drains and sewers into the houses,—gases which are now universally acknowledged to be a prolific cause of typhoid fever, diptheria, and other zymotic diseases,—many plans have been devised to prevent the possibility of their entering the house, such as gully traps, house traps, charcoal traps, swing valves, mercury seals, ventilating closets, disinfectants for neutralizing all effluvia, and a thousand other devices, none of which can be relied upon with any degree of certainty to circumvent the foul emanations. But, as prevention is always better than cure, and however efficient may be the means adopted by which the foul gases generated in, and always present in water-carriage sewers, may be prevented from entering into our houses, or disinfected before they gain access thereto, and, in view of the fact that a large proportion of the defective appliances at present in use, will remain so, it is imperatively necessary that some means should be devised to carry off excrementitious matters and household wastes before fermentative putrefaction takes place, and at the same time to carry off with the material all gases as they are formed, so that they be not allowed to accumulate in the sewers until they become dangerous. Any system that will not accomplish these desiderata is, in a sanitary point of view, absolutely defective.

CHAPTER VII.

Evils Resulting from the Improper Disposal of Sewage.

IT cannot be too often repeated that the "water-carriage" plan of *tout a l'egout* is without doubt the worst devised system of sewerage imaginable for getting rid of excrementitious matters, and should the attempt be made to treat the sewage of Baltimore city in this way, it will undoubtedly prove an expensive and fatal blunder. In the first instance, storm water drains receiving the excremental matters of a population, become so many large retorts circulating through the town for the production and distribution of deleterious gases and germs of disease, and in the next place the ultimate disposal of the noxious liquid after it is out of the city is a question which has not been settled in a manner acceptable either to the interests of agriculture or to the laws of hygiene.

Using rivers and estuaries as receptacles for excretal sewage was at first tolerated on the assurance that it would be unrecognizable to the senses, and consequently wholly inoffensive, through the enormous dilution resulting from admixture with the volume of water receiving it, and minute calculations were produced to prove the degree of resulting dilution. Experience, however, has shown that this argument is a fallacy, inasmuch as the mixing in question does not take place at all. The most offensive solid substances float at first on the surface, and, when the water is a running stream, they are soon deposited on the banks as a noxious mud. In speaking of the sewage of the town of Aylesbury, in England, Mr. George Fell, Secretary of the Local Board of Health, gave the following testimony before "The Judicial Committee of Her Majesty's Most Honorable Privy Council." He said: "In 1875 the river "Thame, which is one of the sources of the Thames, at that "time received the sewage of the town, and a portion of it was "carried in undiluted. Out of the sewage of about 4,000 people, "that of about 1,500 was carried in the tanks and there deposited, "and the overflow ran into the river, and this stream got into "such a filthy state that it was a perfect nuisance. It was "practically a sewer ditch. In fact, I myself, when I have had "occasion to be out late of a summer evening or early of a "summer morning have found a kind of fœted miasma per-"vade the whole air. In consequence of the state of the stream "an injunction was applied for by one of the adjoining land-"owners and obtained, and the town was restrained from "pursuing the course that had been adopted hitherto of turning "the sewage undiluted into the stream."

In April, 1882, Mr. George Tatham, Mayor of Leeds, England, testified before the same committee as follows: "I am "Mayor of Leeds, and it is my third year of office. Sometime "ago the Corporation of Leeds was compelled by proceedings "in chancery to purify their sewage before turning it into the "river Aire. We first had complaints in 1855, and we had to "commence some system in 1869 and 1870, under compulsion "from the Court of Chancery. It was not a question of profit, "but a question of doing the work. We were under the direc-"tion of the Court of Chancery to prevent polluted water from "going into the Aire from our sewers, so as not to create a "nuisance."

Captain Burstall, of the Royal Navy, testified before the same committee: "I am secretary to the Thames Conservancy Board. "I knew the Thames and helped to survey it in 1833. It was "surveyed again by the conservators in 1862, about thirty years "afterwards. By comparison of these two surveys, there was "no difference whatever, scarcely three inches at any place "between the position of the bed of the river with reference to "one common datum in thirty years. This was before the "contents of the sewers ran into the rivers. In 1862 the con- "tents of the sewers of all London began to run into the "Thames, part of them at Barking Creek, and part of them at "Crossness, one being on one side of the river and one on the "other. Very shortly after this, in a very great number of "places in the river, large deposits of black sewage mud were "formed, several of which by my own measuring were from "eight to twelve feet vertically in thickness. A great quantity "of organic matter was mixed up with the mud. Red worms "were also found, not only there, but in the other parts of the "river as well. Those deposits are due to the matters held in "suspension in the sewage fluid which is poured into the "Thames at Crossness and Barking."

Dr. Robert Seely, Health Officer of Aylesbury, states that since the discharge of sewage into the river which borders that town has been interdicted, the miasma and fœted odors which existed have entirely disappeared, and fish have reappeared in the water. He further states that while the sewage of the town flowed into the river, epidemics of typhoid fever occurred from time to time, but since the interdiction of sewage matter, such epidemics have been unknown.

The average volume of sewage discharged from the houses and streets of Baltimore, may be roughly estimated at about 15,000,000 gallons daily, containing in suspension about 40 tons, and in solution about 65 tons of solid matter. Now a portion of the 65 tons of matter in solution is capable of being precipitated, and doubtless by the action of oxidation, as well as of actual precipitation, should it be turned into the fresh water of the Patapsco river, some portion would actually be so thrown down. Consequently, it appears that from 50 to 60 tons of objectionable and putrescent solid matter daily, equalling about 20,000 tons annually, would be admitted into the river and into Chesapeake Bay. The effect of the presence of so large a volume of putrescent matter in the upper bay, placed under conditions favorable for decomposition, can hardly be overestimated. The clothing of the banks of the river and bay with sewage mud, and the mass of gelatinous sewage matter which would accumulate in the bottom of the river and on the shoals of the bay, and which would certaily prove destructive to the fish and oysters, is, apart from the question of sanitation, a convincing proof of the impracticability and folly of ever permitting the sewage of Baltimore to enter Chesapeake Bay.

CHAPTER VIII.

The Principles of Sewage Treatment Classified Under Four Heads.

THE question now arises, how is the sewage of our towns to be treated, as treated it must be, if the health of the inhabitants is to be considered? The methods of treatment or disposal, other than those involved in the system of *tout a l'egout*—sending everything into the sewers—if this indeed may be considered a system at all—and using the sewage in its normal condition and full quantity for the irrigation of land, are pretty numerous and of great diversity of detail, as regards their *modus operandi*; but numerous as they are, they all come under one or other of the following classes:—

1. Keeping the rain and storm waters in drains distinct from those conveying the sewage; the rain water to be passed to river or stream.

2. Dealing with the excreta and household wastes in a special way, altogether separate from the street drains or storm water sewers, leaving these to conduct, in addition to the storm water and street washings, the waste waters of domestic and industrial operations.

3. Precipition or filtration process, by which the solid organic and putrescible portions of the sewage are deposited in a solid form, which can be used as an ordinary manure, passing the liquid portion of it in a condition more or less clear, and free from putrescible matter into rivers and streams, or upon the land.

4. Pneumatic or aspirating process, by which the excrementitious matters and household wastes are forced or drawn through air-tight pipes, as soon as they are formed, by pneumatic suction or pressure, thereby preserving them in a concentrated condition and in a more highly valuable form as a fertilizer after precipitation, as in the 3d process. Thus what is now a nuisance to towns, would become a source of profit to the country generally, and especially to farmers, who would have a valuable manure produced almost at their doors.

CHAPTER IX.

THE "COMBINED" OR ENGLISH "WATER-CARRIAGE" SYSTEM.

THIS system, to which reference has been made in the foregoing pages, exists in nearly all English towns of any size; also in Paris, Brussels, Hamburg, Frankfort-on-the-Main, and a few other Continental cities. It consists in treating all sewage, rain-water, subsoil-water, household and manufacturing wastes alike, by conducting them jointly off in one and the same conduit, a large volume of flushing water serving as a means of conveyance.

While doubtless it is true, as contended by some of the highest authorities, that the mobile vehicle of water is one admirably adapted to aid in the removal of the sedimentary matter usually contained in sewage water, and that the more water you can send down your drains and sewers, the less chance will there be of their becoming choked up with deposits; still, on the other hand, it is equally true that every addition of the moving or flowing force of the sewage matter, obtained by increasing the quantity of water, must of necessity decrease the value of the sewage as a fertilizer. If the object of our town drainage system were merely to convey away the sewage, the admission of water to act as the moving power might answer the purpose; provided the sewers are kept running *full* all the time, otherwise there must necessarily be more or less sliming of some parts of the wall of the sewer, which will readily decompose in the presence of ample, changing currents of air, affording an admirable nidus for the development and growth of disease germs. Concerning this particular danger, Dr. Von Ovenbeck de Meijer, Professor of Hygiene in the University of Utrecht, Holland, and one of the leading sanitary authorities in Europe, thus pointedly speaks: "I cannot conceive how sanitarians venture to say that "in sewers, *running only* ONE-HALF *full*, containing fæcal mat-"ter, and connected with atmospheric air, there is not a good "condition for the growth of germs of disease, or how engineers "can overlook the fact that the 'water-carriage' system leaves "entirely unsolved the important question: 'What to do with "the sewage without involving danger to health?' Every main "sewer not *completely* and *constantly* filled is dangerous to health; "and all sewage containing fæcal matter is a danger to health "wilfully created. *Fæcal matter should never be mixed with other* "*wastes in the centre of population.*"

Again, it is obvious that if the object of a town drainage system be to supply us with a fertilizer, in addition to its other objects, the more water we add to the sewers the further we depreciate the value of the fertilizer. Thus, then, we find, that if we advocate the system of water-carried sewage as the correct one, we are placed in a dilemma out of which it is difficult to escape. "If, to keep the sewage matter as strong as possible "as a fertilizer, we do not use much water, then, by the stoppage "of the drains, or at least the sluggish flow through them, we "do not come up to the sanitary requirements of the question; "we make our drains in fact elongated cesspools."

Enough has been said to demonstrate that "water-carriage" sewers, either on the combined or separate plan is not all that could be desired to constitute a reasonably satisfactory result, but we may epitomise the objections to the system as follows:

1. That as a health measure it is now almost universally condemned by sanitarians and medical men, as absolutely and irreconcilably in conflict with the requirements of modern civilization and the teachings of sanitary science.

2. That refuse matters consisting of excreta and household wastes, solid and liquid, to be discharged properly from towns and buildings, require arrangements separate and distinct from the storm water sewers to be provided, both with regard to the health of the community and the purposes to which these matters may be usefully applied.

3. That the system requires a great volume of water for flushing purposes, which does not always exist in towns, and which, in many instances, it is quite impossible to provide.

4. That it presupposes large expenditures in treating the crude sewage, or it is discharged into water courses, or upon open fields, which not only creates an intolerable nuisance, but leaves the ultimate economy of "the art of sewerage,"—the disposal and utility of refuse matters,—uncared for.

5. That where towns are situated at a low level, in relation to the surrounding country, it is quite impossible to give the sewers the requisite declivity for carrying the sewage with sufficient rapidity to prevent their becoming coated with a foul slime, which rapidly enters into putrid fermentation and evolves gases of the most dangerous kind, containing myriads of microscopic organisms, often of deadly fever germs, so extremely light and mobile, that they are liable to be taken up and disseminated through the town by the moisture which rises from the sewers, or to be drawn or forced into our dwellings through water-closet, bath-room and other house connections, put in, it may be, by some "jerry" builder.

6. That in London, where the system exists in its greatest perfection, it has been found to foul both air and water to such an extent that some supplementary arrangement is deemed necessary, and propositions to this end are now being discussed.

In Paris, where the water-carriage system prevails, the almost constant existence of typhoid fever in an epidemic form has determined the Municipal Council to study what measures can be taken to purify the city, and they have experimented with what is known as the Berlier pneumatic system, which is already in operation in a large area of the city, including the district of the Madeleine and extending from the Place de la Concorde to Levallois-Perret.

The *Pall Mall Gazette* in discussing the subject of the Paris sewers, with reference to the incidence of typhoid fever in that city says:

"It is painfully evident to all persons who have studied the "question that energetic measures must be adopted to preserve "the health of the residents and visitors to Paris. Even the "French press, though not prone to discuss such practical and "prosaic subjects, has taken the matter in hand; and 'Les "Odeurs de Paris' is not only the title of a witty pamphlet by

"M. Francique Sarcey, but has served as the heading for many "a newspaper article. Without entering into technical details or "elaborate statistics, two or three broad facts will demonstrate "how grave the danger has become. Thus, it is calculated that "from 1869 to 1874 the proportion per 100,000 inhabitants who "died from typhoid fever, diphtheria, small pox, measles and "scarlet fever amounted to 150.9; but this figure has steadily "increased, and for the years 1879 to 1883 had more than dou-"bled, the proportion being 334.0. Typhoid fever and diphtheria "were the principal causes of this mischief, and it may be noted "that the death rate from typhoid fever among French soldiers, "amounting to 3.3 per 1,000, is the highest recorded in any "European army. In Paris this fever has become an endemic "complaint, killing about a thousand persons a year, except "when it assumes epidemic violence, as in 1876, when 2032 per-"sons died of typhoid."

In 1880 and 1881 there were more than two thousand deaths from the same cause, and in 1882 more than three thousand inhabitants fell victims to this preventable disease. The greatest evils arise from the barbaric system of drainage, the absence of knowledge as to traps, intercepting, ventilating, &c. There are in Paris 80,000 cesspools, of which only about 60,000 are emptied in the course of the year. All the vegetable matters and household waters drain into the sewers, and there are some 17,000 *tinettes filtres* which, while retaining solids, allow the liquids to escape into the sewers.

The vast dimension of some of the Paris main sewers does not prevent their being denounced on all sides as utterly unsuited for the work to be performed. The fall is insufficient, the water supply inadequate, the solid deposits are so numerous that an army of nearly 1,000 men has to be employed to push the matter along. To drain everything into sewers thus constructed is extremely dangerous. Some of the heavier sewage may remain several weeks in these underground passages before it reaches the outlet, fermenting the while and evolving gases that can enter without let or hindrance private dwellings. The city has nearly 800 miles of subterranean pipes, of which about 500 miles are sewer pipes. The largest of these sewers were constructed at a cost of not less than $60 per running yard; the medium size from $40 to $50 per yard; while the smallest cost from $15 to $20 per yard. The maintainance of these sewers, with 940 "egoutiers," or sewer cleaners, 20 boats and 50 wagons, cost annually $75,000. The maintainance of the sewers and the cleaning of the public ways of Paris figure in the annual municipal appropriations at nearly $5,000,000.

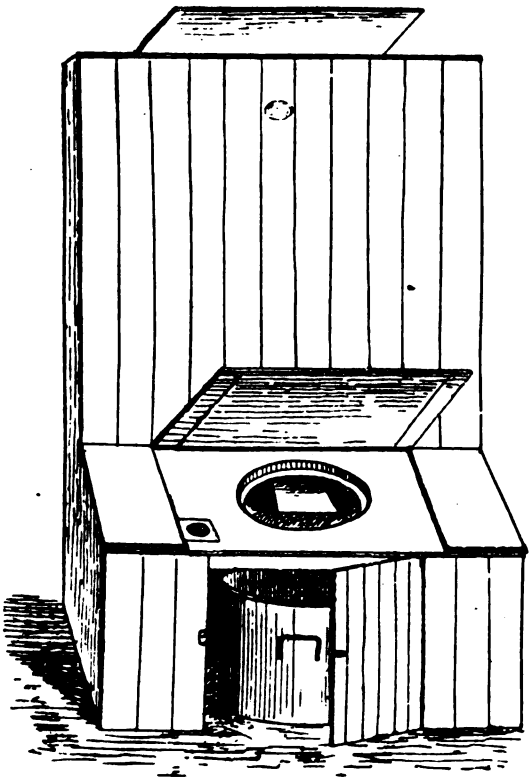
Of course the smaller cities of France are not able to sustain expenditures proportionate to those of Paris, and, consequently, they are all deficient or absolutely wanting in sewers. Marseilles (population 320,000) had no sewers forty years ago. The rain and household waters ran along the streets and emptied into the old harbor; recently, and under the pressure of epidemics, canals have been constructed which convey the sewage waters some distance from the heart of the city. Bordeaux (population 225,000) has only thirty-two miles of sewers in a length of 140 miles of streets. Toulon (population 70,000) has scarcely a vestige of sewers.

It is not to be expected that the smaller towns can bear the burthen of an elaborate system of underground sewers, of which the cost of construction is necessarily very great; but other methods have been devised to meet the difficulty.

CHAPTER X.

THE DRY EARTH CLOSET.

OF the systems which propose to deal with excreta in a special way, apart altogether from the liquid refuse of houses, or the storm water and street refuse, a well-known example is that of the Dry Earth Closet. The deodorizing and absorbent power of dry earth or coal ashes has long been known, but a systematic mode of applying it to the treatment of the excreta of houses is due to the Rev. Mr. Moule, who has introduced several mechanical arrangements by which they can be used. The general principle of these is a receptacle for holding the supply of pulverized earth or coal ashes, a contrivance being attached to it by which, after using the closet, a portion of the dry material is made to cover the excreta. However efficient as a deodorizer and absorbent of fæcal matter dry earth may be—although it is very far from being as efficient an agent in this respect as it is by some maintained to be—it is obvious that there are almost insuperable difficulties attendant upon its use on the large scale, which must prevent it from ever being adopted by towns. There are, moreover, other difficulties attendant upon the use of Moule's apparatus, which will retard its very general introduction even in *country* districts, or for small aggregations of population. The quantity of dry earth required for each time the closet is used is very considerable, and the difficulty is still further increased by the fact that the earth requires to be well dried and in a state of fine division.



DRY EARTH CLOSET.

The mechanical arrangement of the closet is also such, that the covering of the excreta is not always secured; nor is the value of the manure anything like so high as was at one time supposed. This has been conclusively proved by the experiments published a few years ago by Dr. Voelcker in the *Journal of the Royal Agricultural Society of England.* The Diagram is a representation of the earth closet now generally used in this country. The upper portion, or back, is the Earth or Ash Receiver, the lower part beneath the seat contains a galvanized iron pail. The use of earth-closets at the Maryland Hospital for the Insane, adopted after a large sum had been expended on account of litigation for pollution of a neighboring stream, has not proved satisfactory. The closets are near windows, and when the latter can be kept open and the former are well attended to, there is no serious offence in the wards. At other times the odor is perceptible to quite a distance. The use of a sufficient amount of earth of proper quality is often neglected, and the waste from bath-tubs, etc., is so polluting to the stream into which it is discharged, that complaints are still constantly being made.

Mr. Sandford, of England, claims to have overcome the objections to the ordinary earth-closet by his "Carbon Closet."

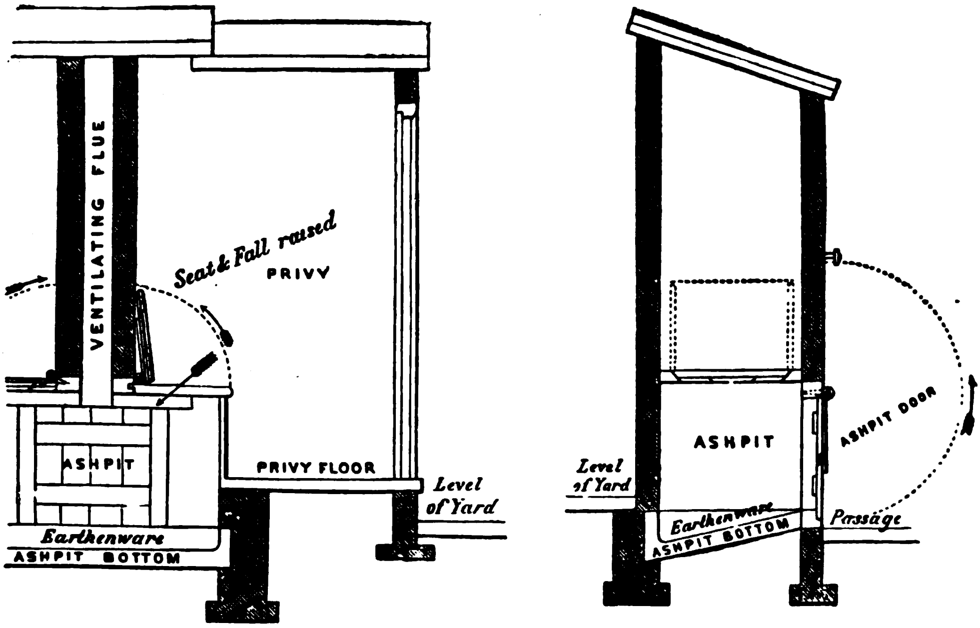
In this the mechanical arrangements are so well devised that the excreta are covered by the deodorizing material with absolute precision and accuracy; and the material employed is dry pulverized charcoal obtained from sea-weed, of which very little is required for each use of the closet. It is also a manurial substance of considerable value when used by itself; but when mixed with the excreta its value as a manure is much increased.

CHAPTER XI.

The Manchester System.

IN the large and densely populated City of Manchester, England, the local peculiarities rendered an adoption of the water closet system on the complete scale, a practical impossibility, not merely from the fact that the necessary supply of water could not at any cost be obtained, but because there was no river near into which the sewage could be discharged, without making it absolutely intolerable from its filthy condition, a condition bad enough at the best under ordinary circumstances. A modification of the "midden and privy system," universally used in the city, was therefore necessitated.

It consists as shown in the diagrams of a common privy, with a small covered ashpit, from the top of which a ventilating shaft is taken to the roof of the house to which it is attached. The floor of the ashpit is of glazed earthenware absolutely watertight and its door, which is either at the side or back, is kept



locked, and only opened by the night soil men when they come to empty it. The ashes can only be emptied into the ash pit through the privy seat, (which is provided with hinges and can be raised entirely for this purpose) and must of necessity be poured over the fæcal matter by hand whenever the privy is used.

The receptacle for excrement is of galvanized iron 15 inches high, 18 inches wide and of a capacity of 10 gallons. The matter is removed weekly for most families, twice or thrice a week for very large ones, fortnightly for very small and neat ones. The addition of dry coal ashes is an improvement, but the metal pail is inferior to the strong wooden one made from the kerosene barrel, such as is used at Rochdale; and the sinking of the pit, in which the Manchester pail stands, below the surface of the ground, is objectionable, as it makes removal more difficult.

Boxes are provided for the miscellaneous solid house refuse, and the house slops and liquid refuse are poured into the sewers through a properly trapped grid in front of the dwelling, and a further improvement is also sometimes adopted by which all continuous communication between the house drains and sewers is cut off, and an escape of sewer gas into the interior is made impossible. The ventilation of the sewers is effected by the down-spouts of the houses, and by street gratings left open for the purpose. The "fall" of the sewers and the consequent discharge of the sewage being so rapid no flushing, as a regular system, is required, although it is occasionally carried out. The escape of sewage gases from the interior of the ordinary drains to those of the houses with which they are connected, is prevented by an ordinary trap.

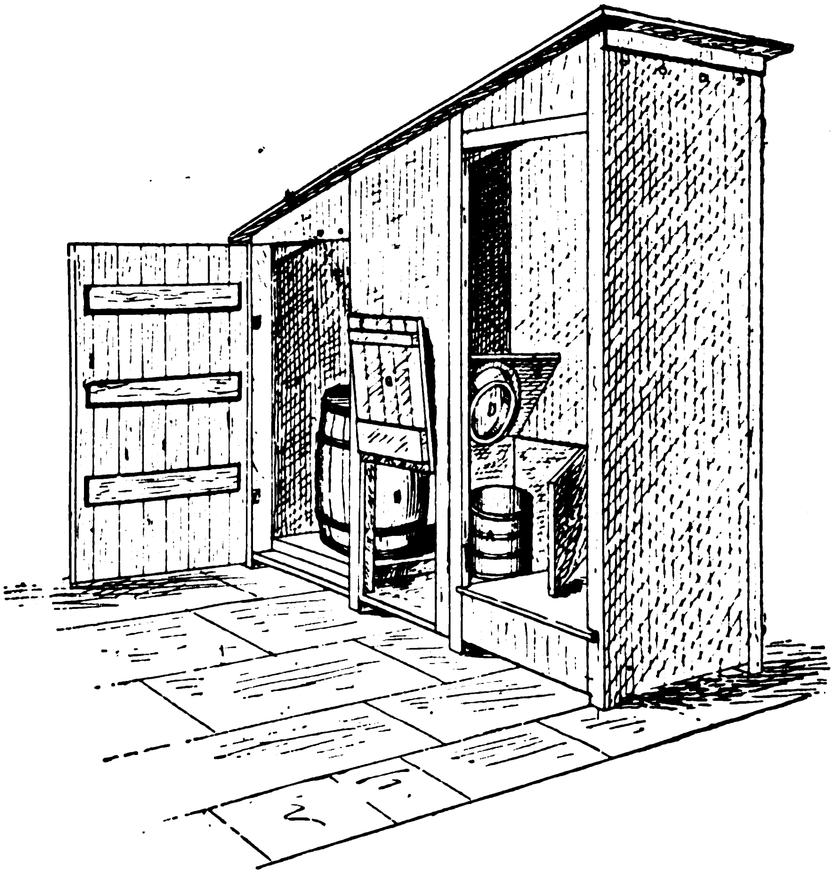
CHAPTER XII.

The Rochdale System.

THE system adopted at Rochdale proceeds upon the same principle as that used in Manchester, the object being the conversion of the old and dangerous system of privy pits into privies calculated to promote health and decency, and keep out from the sewers as much of the excremental matter of the population as possible.

Beneath each closet seat a receptacle, containing a small quantity of a chemical disinfecting fluid is placed, in which the fæces and urine are collected, the vessels being removed in a covered cart in the day-time to a manure manufactory, weekly—or more frequently, if required—an important feature of the process being a retardation of fermentation, so as to prevent the excreta from fouling the atmosphere and being depreciated in value as a manure, which is effected by frequent removal of the receptacles prepared as above stated. The cinders and dry refuse from the house are in like manner collected in common barrels or other receptacles, and, when full, the contents are tipped into a corporation cart and removed to the same depot or manufactory as the excreta, where they are sifted by a winnowing machine, which separates the cinders, refuse vegetable matter, and fine ashes. The vegetable matter is burnt, and its ash and the fine coal ash are used in the manufacture of the manure. There is a ready sale for the large cinders at the price of three shillings a ton, and the smaller cinders are used for working the engine at the manufactory. The fine coal and vegetable ash is mixed with the excreta from the prepared receptacles, the mixture is subjected to a chemical process, and, after being allowed to remain in heaps for a period of about twenty-one days, is passed through a screen to ensure perfect mixing. It is then a damp manure, containing the constituents of the fæces and urine, except a large portion of the water.

By this method of collecting and treating the night soil and refuse of towns there is nothing lost; all is made available, the cinders being found sufficient to raise steam for any motive power required in the process of preparing the manure, and other refuse can be disposed of for their usual purposes. The urine from the public urinals and from dwelling houses, &c., is evaporated and added to the prepared manure. The blood from the slaughter-houses is also, by a simple and inoffensive process, brought into a state fit to be added to the prepared manure, and forms a valuable addition to it. The privies are clean and inodorous, and the plan is certainly a great sanitary and economical improvement over the old privy-pit system.



ROCHDALE PAIL CLOSET.

A. excrement pail.

B. ash tub.

C. seat cover (raised).

D. iron collar below seat, reaching slightly into pail when cover is down.

F. hinged upright of seat.

G door admitting from outside to excrement pail.

Referring to the Manchester and Rochdale systems the Birmingham Sewage Inquiry Committee appointed some years ago to investigate the whole subject with reference to providing a better plan for the sewerage of Birmingham, submitted the following as their general conclusions:

"1. That the privy-pit system in towns or densely populated districts is universally condemned on account of the pollution of the earth, air, and water in their vicinity, which is its inevitable result, and that it is essential to the health, cleanliness and comfort of the inhabitants of such districts that all fæcal matters should be removed with the greatest possible dispatch.

"2. That this can be effectually done by the Rochdale, Manchester or other systems which not only secure the speedy removal of these matters, but effectually exclude both their solid and liquid constituents from the storm-water sewers.

"3. That some such system as the Manchester and Rochdale system is preferable to the water-closet system where there is a difficulty of dealing with the sewage at the outfall.

"4. That the Rochdale system appears preferable to the Manchester system, because it deals separately with the excreta and dry refuse, and renders possible the most perfect and economical utilization of each.

"5. That the refuse from slaughter-houses, public urinals, and cattle markets may be advantageously collected and utilized, &c."

CHAPTER XIII.

The Ordinary Privy Pit.

THE rudest form of domestic accommodation is an open privy pit over a cesspool, such as is used in the City of Baltimore and every village in Maryland. It deserves notice only on account of its dangers and imperfections. These pits or cesspools are almost universally constructed so that their contents drain into and ooze through the surrounding soil, until the whole neighborhood becomes fully saturated with the drainage, which too often finds its way into the water of springs and wells used for domestic purposes, or through some defective foundation, poisoning, it may be, the basement of an adjoining house.

Cesspools constructed of hard brick or masonry and thoroughly cemented, will prevent this saturation, in proportion as their walls are carefully and imperviously built; but the matters daily discharged into such depositories accumulate, and their decomposition is constantly proceeding, and engendering gases of the most noisome and pestilential kind. The open privy formed over a pit of this description affords an outlet for the escape of these gases, which readily and regularly pass into buildings adjacent to or near the privy; or should a water closet connection be made with the privy through the medium of the soil pipe, the effluvia from the cesspit will pass through the pipe into the house, unless the trap is kept well filled with water; and moreover, the supply of water to the water closet will greatly augment the bulk of the sewage, and necessitate the emptying of the privy much more frequently than otherwise, unless some defects in the joints of the work afford a passage for the liquid matters into the surrounding strata, or a communication be made with a drain. These cesspools are at intervals emptied, but never cleaned; the so-called "cleaning" being more a term used than an operation performed.

It is to be hoped that the public mind in every town and village of our State will soon become impressed with the fact that these cesspits give rise to evils of the gravest character, as influencing in a very marked degree the health of those subjected to them; and that it is necessary to introduce a system more in accordance with sanitary requirements and the civilization of the age.

Another point of great importance in connection with cesspools and open privies, with saturated soil surrounding them, is their bearing upon the supply of pure air to our houses. It is easy to perceive that, however well ventilated our apartments may be, the appliances are rendered futile from the admission of tainted air and by the admixture of gases emanating from filthy accumulations of the cesspool and privy. With reference to the impairment of health from this cause, there is no doubt that it is one of the sources which is absolutely necessary to remove, before there can be any effectual cure. Some of the cesspools are in the cellars, and give out their exhalations from thence; others are in a yard, it may be close to a door or window, and the smell from them is often so noxious as to be unbearable. It not unfrequently happens that the occupants of houses thus located have to remain closely shut up, no air being allowed to enter by door or window, on account of the bad smell which comes from the yard.

But if the "mistakes of our forefathers" must still be tolerated, it will be well, at least, to consider how the evil may be measurably mitigated. This is to be accomplished only by proper construction and vigilant supervision. In the first place, the pits should be constructed according to prescribed rules, and maintained under official inspection. Under no circumstances should they be permitted to be placed within the walls of a building, but as far from the dwelling as practicable, and so constructed as to prevent absolutely any filtration into the subjacent soil. They should be conical in form, or at least built without angles, and smaller at the bottom than the top, of such dimensions as will insure against any large accumulation of matter, ventilated by a pipe extending above the building, and provided with an opening outside the privy house, in order that they may be the more easily emptied. The walls of the pit should be at least twelve inches in thickness, laid of hard brick or masonry, in best hydraulic cement, well puddled with clay on the outer side, and cemented, with smooth finish on the inner side to facilitate scraping and washing whenever emptied. The bottom should be of solid slate or masonry laid upon a substantial cemented foundation.

The process of emptying and cleaning the pits is not only troublesome, but, unless properly performed, will occasion great nuisance; it should, therefore, be done at public rather than individual expense, inasmuch as individuals are prone to sacrifice public health and comfort to private interests; but, if this is not deemed practicable or desirable, then the work should be done under strict official supervision, in order to insure the most thorough and efficient cleansing possible.

CHAPTER XIV.

RECEPTACLES OF SPECIAL CONSTRUCTION.

METALLIC RESERVOIRS. It being very difficult to maintain brick or masonry pits sufficiently secure to prevent leakage, it has been attempted to overcome this difficulty by constructing them of iron. When of small dimensions they may be cast in one solid piece, either tubular or rectangular in shape, but should it be necessary to have them quite large they can be constructed of galvanized sheet iron plates securely riveted. They may rest upon the surface or be sunk below the soil, but in either event they should rest upon a secure and unyielding foundation, and be ventilated by a special pipe, unless the soil pipe of the house extends above the level of the roof, which is the case with all houses having water closets in Baltimore. These receptacles occupy much less space than the ordinary pits constructed of brick or masonry, and one reservoir may be arranged to receive the outfall pipes from a number of houses. A reservoir of 65 gallons is capable of receiving daily during ten days 3½ gallons of dejections and as much water. Now as one individual will furnish 40 ounces of urine and 3 ounces of fæcal matter in 24 hours, the reservoir will be sufficient for the excreta of nine persons during ten days, one-half the capacity being occupied by excreta and the other half by water. Each reservoir should be provided with an automatic register or index to indicate when it requires to be emptied. The process of emptying is very simple, being performed readily by the ordinary excavator or pneumatic pump. This arrangement has been used quite extensively in some of the German towns and in St. Petersburg, and, in a somewhat modified form, it was recommended by "The Commission on the Sewerage of Paris" in 1881 (of which commission the *savants* Pasteur and Brouardel were members); but it has never been applied in Paris, on account of the expense involved, which is represented to be very great in large cities where the reservoirs have to be frequently emptied.

THE GOLDNER SYSTEM.—Excretal matter having a density greater than water, M. Goldner, of Baden Baden, has endeavored to utilize this fact by constructing an apparatus in which the excreta will be excluded from contact with atmospheric air by being carried directly under water by gravitation.

A reservoir is constructed of brick or masonry, into which the excremental matter is carried under a bed of water, and remains below until all or most of the water contained in the reservoir is displaced by the liquid and solid excreta, after which the latter is discharged through a system of pipes and used for irrigation purposes. Should the water in this reservoir become contaminated by the diffusion of the liquid excreta it is drawn off and run into the same system of pipes.

The soil or fall pipe, which is from six to eight inches in diameter, passes vertically from the closet above into the reservoirs. The "cuvette," or bowl of the closet, is of special construction, resembling the bowl first used by Capt. Liernur in his pneumatic system, the posterior wall, or back of the bowl being straight to correspond with that of the soil pipe into which it is introduced, so that the excreta fall without interruption into the reservoir. The apparatus will not admit of a soil pipe curved or bent in any part of its course, as it is intended that the excreta shall drop directly down the soil pipe into the reservoir, and, therefore, the latter must be placed immediately under the closet. This apparatus is also intended to be used without any water flush whatever, the bowl being cleansed from time to time or when soiled, by an attendant, with water and a mop. It has been found that the first flow of water over the top of the reservoir, which corresponds in volume with the excretal matter passed below, is quite limpid and pure in appearance, but it soon becomes contaminated and acquires a putrid odor, which indicates that the protective power of the bed of water has been exhausted, and when this occurs the reservoir has to be emptied and refilled with water. It can readily be seen that the plan could not be applied to our American system of water-closets; where there is a large flush of water, and where it would be quite impossible to place the reservoir in every instance directly under the closets; each closet would have to be provided with a separate reservoir.

THE SYSTEM OF DEPLANQUE.—This need only be mentioned in a few words. It has been used in some of the towns of France for a number of years, but, like most systems of the kind, has proved a failure. In the place of mechanical separation of the liquids and solids, M. Deplanque proposed to precipitate the organic materials held in suspension or dilution by lime-water, in order that they may fall to the bottom of the fossa which is to contain them until removed. This fossa or pit into which the material drops vertically through the soil pipe is made water-tight by cement, and is filled with lime-water. When the dejections drop into the water they displace an equal volume of water, which is carried into the nearest sewer by a pipe provided for the purpose, the solid material and precipitate being deposited on the bottom of the pit to be afterwards carted away.

DR. FORBE'S PATENT PRECIPITATING PROCESS has been highly spoken of by scientific authorities, Dr. Voelcker, Chemist to the Royal Agricultural Society of England, among others, having reported favorably of it. The distinguishing feature of this process is the employment of a material which, while it acts as a disinfectant agent, possesses also highly valuable fertilizing properties. The agent employed is the phosphate of alumina dissolved in hydrochloric acid Acting at once as a powerful disinfectant, and adding to the fertilizing value of the clarified and purified sewage, it adds in like proportion to the value of this as an irrigating field.

THE SYSTEM OF SCHLEH.—As the emanations from privies constitute one of their most objectionable features, Mr. Schleh has proposed an arrangement for the absorption of the gases as rapidly as they are formed. The reservoir is to be of iron lined with asphalt; a "trap" or syphon is fixed to the inferior or outfall end of the soil pipe, as well as at the bowl of the closet, which traps are supposed to prevent the gases from entering the house, and, therefore, they are made to pass through a special tube or pipe to two receptacles, the first containing sulphate of iron or manganese, which absorbs the ammonia and sulphureted hydrogen; the second contains sulphuric acid, which decomposes the remaining gases and sets free carbonic acid, which escapes through a pipe passing up to or above the level of the roof. This system has not been practically applied in any place, its advocate resting his claims only on theoretical grounds.

THE GROUX SYSTEM.—This is one of the so-called dry processes. It consists of a movable vessel in the form of a truncated cone, at the bottom of which is placed some deodorizing or absorbent material; then a solid cone or plug, somewhat smaller than the inner side of the vessel, is inserted, leaving between the inner surface of the vessel and the plug a space of 3 or 4 inches which is to be filled with the absorbent material; the plug or mould is then withdrawn, leaving a central cavity which receives the fæcal matters. When the vessel is filled it is covered by a close fitting cover, and in the removal the lining of absorbent material becomes mixed with the contents of the vessel. The lining substance or absorbent material may consist of the general debris of a farm house, such as sweepings, fragments of straw or fodder, chaff, tan, saw-dust, &c., mixed with a small quantity of earth, plaster, or pulverized charcoal. This system has been used in England and France and is said to have given good results, but it requires, as all similar appliances do, great care and constant attention, and is only suited to small villages and country houses.

CHAPTER XV.

Taylard's System for Emptying Cesspools and Privy Pits.

ONE of the most valuable improvements recently effected in the practical cleansing of cesspools and privy pits is a portable pneumatic pumping apparatus recently patented by M. Taylard, of Paris, and improved by Messrs. Charles & Babillat, Mechanical Engineers, at St. Denis, which practically overcomes one of the objections to cesspools, viz., the inconvenience and offensiveness incident to the operation of emptying and cleansing them.

The Taylard system, adapted to large cities, consists of a pneumatic steam pump mounted on wheels, and an air tight iron tank of the capacity of from 500 to 800 gallons, also on wheels. When the apparatus is to be used the tank is connected with the air pump by a small flexible tube through which the air is drawn out of the tank. For towns of less than 15,000 or 20,000 inhabitants, a small air pump worked by hand performs a similar service to that of the pneumatic steam pump. In either case the emptying is effected by creating a vacuum in the tank, which, in turn, is connected with the cesspool or privy-pit by a sectional hose pipe from 3 to 4 inches in diameter, the sectional divisions being either of metallic or flexible material as required—metallic where laid in a straight line, and flexible where it is necessary to bend or curve the pipe. These sections are united by an ingeniously constructed air-tight joint, so that a length of from 50 to 100 yards may be joined in a few minutes. The first section of hose pipe (which is, of course, flexible) is attached to a nozzle provided with a valve at the lower posterior part of the tank, and the last section or house end is immersed in the contents of the cesspool. The air in the tank is drawn out by the aspirating tube connected with the air pump, and the valve of the connecting nozzle being now opened the fæcal and liquid matters contained in the cesspool flow into the tank with great rapidity, the vacuum meantime being maintained by the working of the air pump. Not more than two or three minutes are required to fill the tank, which is provided with a glass tube or index on the outer side, which accurately registers the quantity of matter which has been drawn into the tank, and also indicates when it is full or nearly full. The nozzle with which the first section of the hose pipe is connected is transparent for a short distance, which enables one to see all that passes through it during the process of emptying the cesspool, and this arrangement has led to the detection of certain crimes which otherwise would have passed unnoticed. No odor can possibly escape from the hose pipe or tank, and the mephitic gases, should any exist in the cesspool or pit, are drawn out, and pass directly under the fires of the engine which works the air pump—or, in case the pump is worked by hand, into a petroleum lamp or stove, where they are destroyed by heat. At no time are the offensive matters exposed to the atmosphere or to the view of the public; but they are treated from the beginning to the end of the process *in vacuo*, and consequently the operation is entirely inodorous, clean and expeditious, causing no inconvenience whatever to the occupants of the house or to the neighborhood.

In the case of large cities the tanks are discharged into boats, arranged with air-tight compartments, and the material is conveyed to the place of destination, where it is pumped from the boat by a rotary steam pump into covered reservoirs and chemically treated for agricultural purposes. Where small towns are to be dealt with the tanks are taken some distance in the country and their contents either emptied into reservoirs or spread upon the soil, as may be desired.

In a sanitary point of view this system leaves nothing to be desired so far as the emptying of cesspools or privy pits is concerned. As to the economical side of the question, it may be said that this is by no means a "fixed quantity," since the value of the sewage varies in different localities, as will appear from the following experiences: At Bruges, in old Flanders, the material is very much in request and eagerly sought for by gardeners and farmers; at Blankenberghe, on the contrary, where the soil is strong and does not require this kind of manure, it is difficult to dispose of it at any price. From Antwerp a large proportion of the excretal sewage, transported in boats at small cost, is successfully used upon the sandy fields of "Campine," in the north of Belgium, whereas the same kind of material cannot be used with benefit on the stiff land of the "polders," in Holland.

CHAPTER XVI.

Disposal of Sewage by Irrigation.

WHATEVER changes may take place in the mode of collection and disposal of excreta in the near future, there will, for a long time, remain to be disposed of, in towns having a water-carriage system, an enormous quantity of "sewage"—human excreta, diluted to an almost worthless point with household waste water, and with the storm water and street washings conveyed into the sewers. This material is so dilute that irrigation in one form or another seemed at one time to offer the only chance of utilizing it with any prospect of profit, but in almost every case in which it has been tried it has proved, more or less, a dismal failure.

Mr. John Munro, Professor of Chemistry in the College of Agriculture, Salisbury, England, who has paid great attention to the sewage disposal question, in an able article on the "Composition and Manurial Value of Sewage Sludge," published in the *Journal of the Society of Chemical Industry*, January 29th, 1885, says: "I think I may go so far as to say that the irriga- "tion of ordinary arable land with crude sewage has never "proved successful from the double point of view of avoiding a "nuisance, and of disposing of the sewage at a commercial "profit. There are, of course, several causes for this disap- "pointing want of success, but the chief among them is the "inability of arable soil to deal with a continuous supply of "sewage without great deterioration in its purifying and aerating "properties, so that at last it becomes 'sewage sick,' and in- "efficient as a purifying agent. This is not completely remedied "by 'intermittent' filtration or irrigation, for the land which "has been often covered with crude sewage never recovers, "even by rest, its original efficacy. The commonly accepted, "and, I believe, the true explanation of this is, that the slimy "suspended matter of the sewage gradually chokes the pores of "the soil, forming a deposit impervious to air, and thus prevent-"ing the aeration essential to nitrification, and on the other "hand, encouraging putrefactive fermentations."

A very little consideration will show that water-carried sewage is not quite what one may call a "portable" article, that the farmer cannot order a *ton* of it, as he would of guano or of super phosphate, even admitting that—which we have seen cannot be admitted—it is as valuable to him as these well-known manures. The chief, if not the only, source of manurial value in town sewage is the excreta of the population. All the organic matter is useless from a money-point of view, and it is likely to be prejudicial to the land. At all events the matters in sewage, other than human excreta, if not positively injurious to land, are certainly not necessary or desirable. The saline matter of excreta alone is useful, as it closely resembles the saline matter taken from the land by plants, under ordinary circumstances.

" Every living being," says Liebig, "produces in its offal the "manurial ingredients, both quantitative and qualitative, re-"quired for reproducing the means of sustaining life. It is the "law of the circuit of atoms, each playing a part in a long-"stretched series of acts of nature, serving consecutively various "purposes, and beginning the series anew each time the circuit is "completed. Thus the dung of cattle contains all fertilizing "properties needed for growing their food, whilst that of car-"nivorous animals supplies the manure for producing the food "of the creatures on which they prey; and so it is with every "living being, including man. Hence it is unquestionable that "the nitrogen, phosphorus, phosphoric acid, potash, and other "organic and inorganic matters contained in the excretal sew-"age of cities will suffice for producing food for the people it is "derived from."

We come now to notice the drawbacks and difficulties attendant upon any system of irrigation. In the first place, land cannot be obtained of sufficient extent in the neighborhood of towns in which sewage is produced; and this may safely be accepted as the rule when we consider that one acre is required in ordinary irrigation for every thirty to forty individuals of the population. The land, moreover, must be, to give the best results, of a certain quality, and its surface arranged in a certain way, and at great expense before the best results of the application can be secured. There may be no great difficulty in dealing with the sewage of a small town; but in dealing with that of a large and densely populated city like Baltimore, the circumstances are so materially different, that, as is well pointed out by Mr. Hawksley, the eminent English engineer, the difficulty may become incalculably greater.

It has already been shown that the purifying effect of an area of land continuously used for purposes of irrigation is not lasting, and that ultimately the soil becomes so saturated that a serious nuisance, both disagreeable to the senses and injurious to health, is the result. On this point the experience of Mr. Hawksley, as stated in his evidence before a Committee of the House of Commons, may be quoted. He says:

"Sewage irrigation carried on in warm weather is exceed-"ingly unhealthy. * * * * I can speak positively to it from "repeated observation in different places, that the odor, particu-"larly at night, and more particularly upon still, damp evenings "in autumn, is very sickly indeed, and that in all these cases a "great deal of disease prevails. * * * * The sewage forms a "deposit on the surface of the ground, that deposit forms a cake "of organic matter, and that organic matter when it is in a "damp state, as it usually is, gives off in warm weather a most "odious stench."

The following from a *Report of the Town Council and Board of Police*, Glasgow, 1878, upon the methods of disposing of sewage adopted in various towns in England, bears upon the same point. "Great hopes were a few years ago entertained "that in irrigation had been found the grand solution of the "sewage question * * * * All that is changed now. Sew- "age farms on which immense sums of money have been "expended have been reluctantly abandoned, and irrigation is "no longer regarded as any thing more than a means of obtain- "ing a good effluent."

The experiments of Dr. Frankland and others, it is true, show that it is possible, by means of an acre of properly drained and prepared soil, six feet deep, *used intermittently*, to effect the purification of the sewage resulting from a population of several hundred persons, but the land must be kept in such a condition that it can readily absorb a fresh supply of oxygen to bring to bear upon a further quantity of sewage. "It is not "unlikely," says Dr. Frankland, "that the operation, involving "as it does the exposure of large and offensive filtering beds to "the air, would be itself attended with much serious nuisance."

But admitting that land can be obtained, and that the passage of sewage water *through* a properly prepared filtration area of soil effects a purification far in excess of the effect which would be produced by irrigation *over the surface* of the same area, the enormous expense of preparing the filtering beds is an insuperable obstacle.

Mr. Baldwin Latham, of England, now so well known in connection with sanitary engineering, in his testimony before the Judicial Committee of the Queen's Council in 1882, referring to the process of irrigation by intermittent downward filtration (passing intermittently sewage water down through the soil), said: "I have been engaged professionally for a large "number of corporations—over one hundred. I have carried "out the principles of irrigation works myself at Croyden, "Rugby, Warwick and many other filtration works as well. "The sewage of 1,000 people may be applied to one acre of land "by '*intermittent filtration*' only; but it is extremely costly to "lay out the land for filtration purposes. It costs a very large "sum of money to prepare the land for that process. I have a "case at present in hand at Menton for the Croyden Rural "Sanitary Authority. There we apply the sewage of 1,000 "people to an acre, *but that land has cost over* £300 ($1,500) *per* "*acre to prepare it for the purposes of the treatment of the sewage.*"

In addition to the enormous cost of preparing the land, as given by Mr. Latham, one of the first engineers and sanitarians in Europe, there is another great drawback to the process of irrigation, especially where small areas of land are used. How would it be possible to get the whole of the rainfall over a large city dealt with in this way by a small area of land? There would be at times enormous quantities of water coming down the drains and mixing with the sewage, which would have to go somewhere, and therefore, however perfect the process might be for dealing with a certain amount of sewage, and with a certain area, there would be times when it would be impossible to deal with it effectually.

In the discussion, already referred to, on the Disposal of Sewage Sludge before the Society of Chemical Industry, in London, 1884, Maj. Flower stated that the chemical treatment of sewage was resorted to "because the irrigation farm became "such an abominable nuisance," but he adds: "The Enfield "people had, unfortunately, contrary to my advice, taken to "irrigation again, for the Company which undertook to treat "the sewage by Whitthread's dicalcic phosphate process had "broken up, and they again found how horribly deficient irri- "gation was, especially when the sewage was poured into a " water-logged stratum."

At the same meeting, the President of the Society, Mr. David Howard, said: "It must be borne in mind that at best "sewage precipitation is only a palliative; the land itself "must take what remains in solution; but those who have "seen the working of a sewage farm well know the ineffable "abomination of applying unfiltered sewage to land in large "quantities."

Evidence of a similar nature could be multiplied to almost any extent, but enough has been adduced to show that irrigation can never be practiced with any measure of success either from a sanitary or economical point of view, without first removing the putrescent solid suspended matter, either by subsidence or partial chemical treatment, in order to avoid the clogging of the pores of the ground and the formation of a film of putrefactive matter, injurious alike to the health of the neighborhood and the vegetation of the ground itself.

CHAPTER XVII.

THE "A B C" PROCESS FOR PURIFYING SEWAGE.

THIS process, first patented by Mr. Sillar, of England, consists in thoroughly mixing the sewage with certain proportions of alum, blood, clay, charcoal and certain other substances, allowing the mixture to remain quiescent for a time, or until the solid matter is deposited. The effluent water, more or less purified, is allowed to run off in the sewers or river, while the solid matter is manipulated and dried, and is then ready to be sold as a manure. This process is now being worked at Aylesbury, a town near London with a population of about 8,000. It has also been tried experimentally at Leeds, Leicester, Bolton, Leamington, Crossness, Paris and Brussels with satisfactory results, foul sewage being converted into clear, inodorous, effluent water.

At Leeds and Leicester the town authorities were able more economically to get rid of the sewage matter so as to meet the requirements of the Pollution of Rivers Acts, and the process was discontinued. At Leeds the authorities found that the river Aire, which received the effluent discharged from the sewage works, was so foul from other causes and smelled so badly that it was considered a pity to waste the taxpayers' money by purifying sewage which passed into it. The argument was, "the river " is so bad, it is almost as bad as the sewage itself, and therefore " it is not worth while to waste money simply to throw clean " water into this dirty river," and they accordingly returned to the plan of "all to the river." At Leamington irrigation has been adopted, and at Paris experiments are being made with a pneumatic process which is rapidly growing in public favor, and will most probably be adopted as the general system for the city. At Brussels the water-carriage system is in operation and the sewage continues to be discharged into the Seine without any treatment, notwithstanding the polluted condition of that river. London is still in a dilemma as to what disposition to make of the 150,000,000 gallons of sewage now discharged daily into the Thames at Crossness and Barking; but the experiment with the A B C process at Crossness has been highly commended by such eminent authorities as Prof. William Crookes, Fellow of the Royal Society; Dr. Charles Meymott Tidy, member of the Royal

College of Surgeons and of the Society of Chemical Industry; Prof. John Thomas Way, of the Royal Agricultural College; Prof. William Wallace, Fellow of the Royal Society of Edinburgh and Public Analyst of Glasgow; Mr. Thomas William Keates, Fellow of the Institute of Chemistry, London, and Consulting Chemist to the Metropolitan Board of Works; Maj. Lamorock Flower, Consulting Sanitary Engineer to the Lee Conservancy Board; and also by Messrs. Baldwin Latham, Charles Hawksley, Norman Bazalgette, and E. K. Burstal, Civil Engineers, and a number of farmers, gardeners, &c.

The following is a brief description of the usual method of working the A B C process:

The sewage is delivered at the works through an oval pipe about 2 feet in the longest diameter, into a small oblong space about 4 feet wide by 6 feet long, paved with bricks. Across this space, and about one yard from the sewer mouth, a wooden V-shaped trough is placed, into which the B C mixture is run—even distribution into the sewage being effected by means of numerous notches cut on the sides of the trough. By this means the sewage is completely and immediately deodorized, no escape of offensive odors from the sewage into the surrounding air taking place. The entire works are free from any objectionable smell whatever. After being mixed with the B C mixture the sewage passes through an iron grid for the purpose of catching paper, straw, and similar floating materials. It then passes along a brick-paved channel for about 12 feet, the channel afterwards narrowing to 2 feet in width. Here the A (alum) solution flows in from a wooden trough in the same manner as we have described in the case of the B C mixture. The alum, it will be noted, is added some time after the B C mixture. The addition of the precipitating ingredients separately, we are informed, is found to afford better results than when they are run in together.

The treated sewage flows along the two-foot channel for about forty yards, in order to facilitate mixture, before it is allowed to run into the first subsiding tank. There are three subsiding tanks, each holding 42,000 gallons, through which the treated sewage successively flows before finally passing through a fourth and last tank, which is about double the size of the other three. On leaving the tanks the effluent, now practically free from suspended matter, and devoid of smell, passes for several hundred yards along an open brick channel before finally discharging itself into a water-course or upon the land.

The principal materials used for the precipitation of the sewage matters are clay, carbon, blood and alum, and they are manipulated as follows: Weighed quantities of the clay and carbon are ground together in a mill with a certain small proportion of blood and some water. When thoroughly incorporated, the mixture is run into a reservoir placed beneath the mill, where a considerable proportion of the heavier clay particles subside, whilst the lighter particles of clay and carbon are added to the sewage as before described. The sulphate of alumina is dissolved in a separate tank, and is run directly from this into the sewage. The solution of alum used is found to contain, on an average, from 1 to 2 per cent. of sulphate.

The Rivers Pollution Commission's Report (England) for 1870 gives the following list of the ingredients of the A B C compound, which are varied, however, according to the nature of the sewage to be purified:

Alum	600	parts.
Blood	1	"
Clay	1,900	"
Magnesia	5	"
Manganate of Potash	10	"
Burnt Clay	25	"
Chloride of Sodium	10	"
Animal Charcoal	15	"
Vegetable Charcoal	20	"
Magnesian Limestone	2	"

The blood acts simply as albumen ; it acts towards the suspended matter in the sewage very much like the white of an egg does in clarifying coffee. It is coagulated by the alum (when used in coffee the albumen is coagulated by heat), and it takes hold of the solid matter that is suspended in it, and in the act of coagulating it entangles the solid matter and carries it down to the bottom. Blood is used in a great many chemical operations for the same purpose, and we know that very small quantities of albumen will produce very large effects. The action of the clay is chiefly mechanical; being heavier than the lighter matters held in suspension, it carries them down bodily; and it probably also exercises a chemical action in absorbing the ammonia. The animal and vegetable charcoal is also of great chemical value in absorbing the ammonia, but it is really not necessary to have both animal and vegetable carbon,—either the one or the other will answer the purpose. The magnesia in some cases acts chemically, but in most cases it is not of much value; the manganate of potash is of very little value, and chloride of sodium is of no value, except as an antiseptic.

As to the results of the application of the A B C Process in purifying polluted sewage, the Report of Dr. Tidy and Prof. Dewar, made after a lengthy and exhaustive examination of the process, and published in June, 1885, establishes the following facts:

1. That the A B C Process produces a clear effluent, free from suspended matters and devoid of smell.

2. That the effluent is uniform, notwithstanding the very varied nature and concentration of the sewage.

3. That as the strength of the sewage increases, the precipitation is more complete.

4. That the process removes over 80 per cent. of the total oxidizable organic matter.

5. That it precipitates 60 per cent. of the organic matter in solution, and of the residue left in the effluent at least two-thirds are not albuminous, and, therefore, of a nature less liable to putrefactive and other changes.

6. That the process is carried on without nuisance, the sewage being immediately and completely deodorized, and the entire works free from any objectionable smell.

7. That it produces a manure containing an average of 3.8 per cent. of ammonia calculated on the perfectly dry manure, or if with 20 per cent. of water, 3 per cent. of available ammonia, and also 5 per cent. of phosphates reckoned as tri-calcic phosphate of lime.

With such testimony as the above, supplemented by that of other well-known sanitary authorities as Prof. Wallace, of Glasgow; Prof. Way, of the Royal Agricultural College; Mr. Collingridge, Sanitary Officer of the Port of London; Major Flower, the late Mr. Keates, Mr. Baldwin Latham, Mr. Hawksley, Mr. Bazalgette, and the Mayor of Leeds, it is hard to resist the conclusion that it is at least an available process for purifying sewage. But regarding it from a medical and sanitary point of view, which we are bound to do, the most remarkable fact is the actual absence of any offensive smell about the works. Either the process is very successful, or it is very carefully worked.

CHAPTER XVIII.

OTHER METHODS OF TREATING SEWAGE.

IN a paper read before the Society of Chemical Industry, London, 1884, Mr. C. C. Hutchinson discusses various processes for purifying sewage, of which the following is an epitome:

He sums up with the statement that the conditions of modern sewage disposal point to the direction of keeping the whole of the solid matters and excreta entirely separate from surface drainage and rainfall, because in dealing with a less bulky and dilute material it renders the process of purification and disposal much simpler and less costly. To this end, he thinks that in all towns which are not fully sewered, a separate system of surface drainage should be carried out for taking off the whole of the rainfall which may pass into the water courses sufficiently pure without any treatment. In those towns which already have a complete system of sewerage into which everything falls, the plan is being adopted of providing storm overflows, the sewers being so constructed that when a certain quantity of water has accumulated in them the remaining part, due to storm, flows over without any treatment into some stream or water-way. He believes that in simple subsidence, without chemical treatment, it is practically impossible to settle out the whole of the putrescent matter in sewage, and that about five-sixths is precipitated in the form of sludge.

CHEMICAL PRECIPITATION.—Sewage sludge, as left after precipitation, is defined by Mr. Hutchinson to be a thin mud containing from 90 to 95 per cent. of water, the remaining part consisting of the solid matter, organic and mineral, originally suspended in the sewage, a small amount of the soluble organic matter precipitated by the chemical reagents, and more or less of the reagents themselves used for defecation. The large quantity of water it contains renders it exceedingly bulky, and this, together with its offensive character, constitutes the chief difficulty of its treatment. Unless deprived of the greater portion of its moisture, it enters into putrefactive fermentation of a more or less violent and offensive nature. As obtained from the various chemical processes, it is yielded in quantity equivalent to from 1 to 125 tons for every thousand inhabitants contributing to the sewage.

The objection raised to chemical precipitation is that, no matter what special reagent is used, the ultimate difficulty is the same, namely, the disposal of the large accumulations of sludge. In a paper read before the Institution of Civil Engineers, of London, by Mr. C. Norman Bazalgette, the author stated, as an objection to chemical precipitation, that "it is impossible to manipulate the enormous accumulations of sludge "necessarily incident to treatment by chemicals," and further, that when chemical treatment preceded natural filtration, "the "accumulation of sludge is an objection inseparable from the "use of chemicals."

EVAPORATIVE METHODS.—Mr. Hutchinson states that no process which depends upon the application of artificial heat can meet with any degree of success, (1) on account of the expense they entail both for fuel and labor; (2) the pollution of the neighborhood of the works by offensive odors invariably given off. The removal of the water by evaporation, as will be apparent, is infinitely more complex than the simple evaporation of water in an ordinary boiler, in which, under ordinary circumstances, good fuel will evaporate from 7 to 9 times its own weight of water. So high an evaporative efficiency is impossible with sludge, and it is more than probable that not more than one-third such effect has ever been attained. Upon this basis of calculation, the following shows the quantity of fuel required for reducing the sludge to a condition in which it can be easily handled, containing 50 per cent. of water.

One ton of wet sludge contains:

Solid matter	(10 per cent.)	2 cwt.
Water	(90 per cent.)	18 cwt.

A sludge yielded by drying down to 50 per cent. moisture contains:

Solid matter	2 cwt.
Water	2 "
Coal required to evaporate 16 cwt. of Water	6 "

MILBURN'S MACHINE.—The cost of drying by Milburn's Machine, at one time in use in several sewage works in England, has been stated to be in one instance $5 per ton, and in another $7 per ton. Such an expenditure cannot, with a material of so little value, offer any hope of success, and accordingly, we find that machines of the evaporative type have been altogether abandoned.

MECHANICAL METHODS.—Under this head Mr. Hutchinson first notices the method of disposing of the wet sludge by pumping it direct from the tanks on to land, into which, after air drying, it is dug. At Birmingham the sludge produced by lime treatment, amounting to upwards of 350 tons per day, is got rid of in this way, and it was originally thought that it would so quickly rot away, that within two years the same land could be used over again. Such, however, is not the case. In 1877, Mr. J. Mansergh, C. E., stated: "Such a process as that of "digging in the immense quantity of sludge produced by the "lime process at Birmingham was unlikely to be of long dura- "tion," and his remarks have been fully borne out. Ninety acres of land are required for this purpose, and if continued much longer, it cannot be denied that the whole area must ultimately become a mass of sewage filth. In 1876 the cost of removing from the tanks and digging in 109,500 tons was nearly $55,000 or about fifty cents per ton.

MONSON'S PROCESS.—Mr. E Monson has proposed to deal with the sludge by making it into bricks, the manufacture so carried out effecting a return for the expenditure upon the purification. This plan was tried in one or two cases, for instance, at Leicester and Birmingham, but it not does seem that it was ever adopted. Brick-making, as already pursued, is an industry far from being agreeable; but what it would be, if in addition there should be added those infinitely worse odors of first baking, and then slowly burning the organic matters contained in the sludge-made bricks, can perhaps be better imagined than described.

THE GENERAL SCOTT PROCESS.—This consists in precipitating the solid matters of the sewage by milk of lime. The sludge resulting from this process of precipitation, composed of lime and certain organic matters, is dried and burnt, and the residue is ground and made into a cement similar to Portland cement. This process is used at Burnly, England.

THE VON PODEWIL OR AUGSBURG SYSTEM.—This system, which is in operation in Augsburg, Germany, consists of covered reservoirs from which the sewage matters, liquid and solid, pass into a mixing cylinder, where, for the purpose of fixing the free ammonia, it is treated with sulphuric acid, and then conducted by iron pipes to heated compartments, where it is dried and finally passes out as a dry manure powder or *poudrette*. The state of the temperature is regulated by an index or gauge attached to the apparatus. The gases set free during the drying process are conducted under the fire of the engine, where they are consumed, leaving no unpleasant odors. The dry powder resulting from the process is said to be unobjectionable from a sanitary standpoint.

The experiments at Augsburg, not including the factory and machinery, have cost over $50,000. Augsburg has a population of about 50,000 inhabitants.

CHAPTER XIX.

Johnson's Filter Press.

OF the many processes for mechanically dealing with sewage sludge which have been proposed, the most successful is that of Messrs. S. H. Johnson & Co., of Stratford, England, which has been more than two years in operation at Coventry, England, and which has been subjected to experiments by the Metropolitan Board of Works, with the result of the Board's voting a further sum of £5,000 for more extensive experiments, with a view to its application to the metropolitan sewage.

The following description of the apparatus is quoted from a paper "On the Disposal of Sewage Sludge," read before "The "Society of Chemical Industry," London, by Mr. C. C. Hutchinson, a member of the firm of S. H. Johnson & Co.

"The filter press consists of a number of narrow cells held "in a suitable frame, the interior faces being provided with "appropriate drainage surfaces communicating with an outlet, "and covered by a filtering medium, generally cloth or paper. "The interior of the cells so built up are in communication "directly with each other, or with a common channel for the "introduction of the matter operated upon, and as nothing intro-"duced into the cells can find an exit without passing through the "cloth, the solid matter fills up their interior, the liquid leaving "by the drainage surfaces. The cells of the machine being sub-

"jected to an hydraulic pressure, which increases as the opera-"tion goes on, and as the growing resistance offered by the "increasing thickness of solid matter on the cloth, must of ne-"cessity, on their exterior touching surfaces, be mechanically "made true and pressed together with force sufficient to prevent "the material operated on escaping. The force exerted upon the "material driven into the press, whether by a pump or other "means, must be considerable, and as both sides of a cell are "subjected to the same pressure in opposite directions, it fol-"lows that if nothing, such as a local stoppage, interferes with "this equality of pressure, the diaphragms are in equilibrium "as regards pressure.

"To be of any utility, in dealing with daily accumulations "of sludge, the machines must be of considerable size, because "even for a population of 30,000 about 30 tons have to be dealt "with during the day. Difficulty of making large plates suffi-"ciently rigid and tight at once appears, but as far as this is "concerned it has been met by adopting the circular shape, a "form which above all others for strength and resistance to the "internal fluid pressure is at once apparent to the mechanical "mind. It would be impossible to enter into all the minor "details of construction which experience has proved to be "necessary to success, but although not here noticed they are "none the less important, as each in its particular manner con-"tributes to the result; only the leading and most vital features "will therefore be dwelt upon.

"The most disastrous difficulty we have had to contend "with has been the stoppage of the feed passages, due to the "heterogeneous character of the rubbish and fibrous matter "present, which only too easily builds itself up, whenever the "least excuse offers, into hard blocks. The inevitable conse-"quence of the stoppage of any of the chambers is that the "equilibrium of opposite pressures on each side of the adjacent "cells is destroyed, and the plates even under moderate pressures, "unless made of a thickness quite impracticable, collapse and "break, a result which the usual size of the machines, 3 feet and "upwards in diameter, readily encourages. For example, at "Coventry the employment of two such presses each with 30 "plates led to the destruction of no less than upwards "of 60 plates in a few weeks from no other cause. The "remedy for this is as efficient as it appears simple. "Instead of the central parts of the cells being kept "entirely apart, suitable shaped projections are formed "on their surfaces, which are faced down to the same "plane as the exterior joints, so that when the machine is "screwed up, these nip the cloths between them, and bearing "upon each other form a series of stays from one end of the "machine to the other, supporting the plates when the equilized "pressure is destroyed, until the higher pressure forces the "obstruction away. Since the introduction of this simple device, "no fracture has occurred in any machines to which they have "been applied, and experience enables me to state positively *that, "without such a method of support, no filter press can be success-"fully used for sewage purposes.*

"Another requirement equally important is the mode of "introducing the sludge into the press. In most cases of filtra-"tion an hydraulic pump is used, and where the matter is not "too thick and contains *little or no fibrous matter*, answers "sufficiently well with small quantities. But we speedily found "that with the mass of fibrous matter and rubbish with which "we had to deal, the valves of the pumps continually became "choked, and operations were inevitably interrupted at the "most vital period. The large quantity of gritty, silicious "matter, as would be expected, rapidly cut the working parts "to pieces. The plan has therefore been followed of running "the sludge, or drawing it by vacuo, into cylinders placed "underneath the presses, and large enough to contain a charge. "From this vessel it is forced by compressed air, of a pressure "of 100 lbs. to 120 lbs. per square inch, into the press, the air "being supplied by a suitable compressor, pumping in the case "of two or more presses into a storage vessel. The press is "thus instantaneously filled, filtration commenced immedi- "ately, and the whole operation is completed in about one "hour. The advantages of the compressed air system are "many besides those which have been shown. It is found to "be more economical than employing pumps, if the quantity "of material to be operated upon is large. It is of course "evident that as the filter press operation approaches com- "pletion less material is required. With a pump this would "escape through the relief valve and the power be lost; with "compressed air, working on an elastic medium, the speed of "the compressor can be kept constant and the power stored up, "ready to be drawn upon when required. Again, pumps must "not be worked for such a purpose above about 40 strokes per "minute; consequently, the rate of feed at the commencement "of the pressing is too slow; an efficient air compressor can be "constructed to run at 100 strokes per minute, and therefore, "irrespective of air accumulated, the press can be fed rapidly, "economy of time being the result; other important advan- "tages could likewise be enumerated."

The addition of a small quantity of fresh lime just before pressing considerably adds to the facility of the operation.

The results of the operation briefly described are: Within one hour every five tons of wet sludge containing 90 per cent. of water can be deprived of 88 per cent. of its water, giving a residue of one ton of hard-pressed cake, containing 45 to 50 per cent. of water. The cake so obtained is easily handled, is practically inodorous, air dries very rapidly, and does not again enter into fermentation; it can be kept for any length of time without smell or nuisance. In this condition it can be disposed of in the immediate neighborhood as manure, for which purpose, as will be noticed, it is available. How far further expenditure, having fulfilled the sanitary requirements of the problem, is justifiable upon a material of so little value, can be judged of from the records of past experience; but whatever its ultimate destination, there can be little doubt that the condition in which it leaves the filter press is that in which it can be most cheaply dealt with, whether for purposes of utilization or destruction.

In dealing with the sludge from a population of 30,000, the following apparatus is used:

Air compressor, air accumulator; two sludge filter presses, three feet diameter; two sludge forcing vessels, with their fittings and the various distributing pipes for sludge and air; a tip truck and tramway for the removal of the pressed cake discharged from the machines.

The cost of such a plant with the requisite boiler power (about 10 H. P. actual) is about £1,000. Thirty tons of wet sludge can be easily pressed into cakes, containing 50 per cent. of moisture, equalling six tons, or one-fifth of the original bulk, consisting of 5 charges from each machine of 12 cwt. each in 10 hours. The labor required is about two-thirds of the time of two men.

The cost of the operation, determined from actual work extending over two years at Coventry, amounts, with all expenses included, to sixpence per ton of wet sludge, or half-a-crown per ton of pressed cake, and on a larger scale this expense will be somewhat less.

Mr. Hutchison thinks that the idea of converting sewage residual into manure, yielding a profit upon the whole operations of sewage treatment, may be viewed as fallacious, and he refers to the failure of the many plans tried with this object.

There is, however, no reason why sewage sludge, when deprived of its water, should not be so used, and although too poor to pay the expenses of carriage to a distance, when filter-pressed, it can be profitably employed by the farmers in the immediate neighborhood. At Coventry this has proved to be the case, for whereas the partially air-dried sludge had either to be given away or got rid of at a charge to the works, the filter-pressed sludge is purchased by the farmers at 3s. 6d. per ton and upwards.

It is, however, by no means put forward that this should be the object of so treating the sludge; that must ever remain a sanitary necessity, but as occasion offers it is evident a reduction of the working expenses can by this means be effected, especially if a little care be exercised in handling it after it leaves the filter press. Air-dried, it parts with its moisture readily, and the amount of water can thus easily be reduced to 20 per cent., in which state it can, if desired, be easily ground. Being so deficient in those elements which constitute the value of a manure, it cannot of course be taken upon the same basis as artificial manures. There is, however, no doubt that it is equal to, and in some cases more valuable, according to analysis, than farm-yard manure. Having regard to the fact that the usual price of the latter never exceeds one-half its analytical value, sewage sludge, with which it fairly compares, should be valued on the same basis. The following examples are selected from results given by the sludge from different systems of treatment, taking into consideration the nitrogenous matter and phosphates only.

Nitrogen calculated to ammonia is taken at 6s. per unit. Phosphoric acid calculated to neutral phosphate of lime at 6d. per unit. The resulting values are shown both for cake containing 50 per cent. moisture as coming from the filter press, and also cake air-dried down to 20 per cent. moisture.

From the following analysis it will be seen that the value of the pressed sludge is fully equal to that of farmyard manure; and this statement is borne out practically by the statements of Lieut.-Col. Jones, V. C.: "He had tried sewage "sludge side by side with farmyard manure, and with 60 per "cent. of moisture it was, bulk for bulk, rather superior to the "manure."

Sludge from Treatment of	Pressed Cake 50 Per Cent. Water.				Air-Dried Cake 20 Per Cent. Water.			
	Ammonia.	Phosphate of Lime.	Value per Ton.		Ammonia.	Phosphate of Lime.	Value per Ton.	
			s.	d.			s.	d.
Sulphate of Alumina and Lime	0.84	1.81	6	0	1.36	2.9	9	7
Lime	0.5	2.06	4	0	0.80	3.3	6	5
A. B. C. Process	0.69	0.65	4	6	1.10	1.04	7	2
Hanson's Process: Alkali waste and Lime	0.5	0.98	3	6	0.80	1.57	5	7
M. & C. Process: Lime, Carbon, Soda and Perchloride of Iron	0.62	0.86	4	2	1.00	1.37	6	8
Paris Sludge from Pneumatic System, treated with Sulphate of Alumina	2.20	7.5	17	0	3.52	12.00	27	2
Manure made from Pail emptyings—Goux System	0.82	0.96	5	6	1.31	1.57	8	9

Before leaving this part of the subject, attention may be directed to the result shown by the manure made from pail emptyings, and it will be seen that, even after the expense of separate collection is incurred, the result is of no more value than ordinary sludge, fully establishing from this, as well as from a sanitary point of view, the inefficiency of such processes. The high value of the pressed sludge from the pneumatic system of collection is easily understood: collected by a pneumatic system, all else save excreta, urine and a minimum quantity of water is excluded, and, after treatment with a small quantity of sulphate of alumina, it forms, when pressed up into cakes by the filter press, a manure far richer than any sludge from water-carried sewage.

CHAPTER XX.

Pneumatic Systems of Sewerage.

THE problem of rendering cities healthy by the rapid removal of excrementitious and household wastes is in a measure solved when we can get rid of such matters without any possible connection between them and the surrounding air and soil. The advantages of a pneumatic system may be briefly stated as follows:

1. It prevents the emanations which a protracted stagnation of excrementitious matters will give rise to, when the dejections are deposited in cesspools or cesspits in or near dwellings, or are allowed to decompose in large water-carriage sewers.

2. It prevents the introduction of dangerous matters into sources of drinking water and into the surrounding earth, and thereby greatly lessens the danger of epidemic diseases being transmitted through infectious germs contained in fæcal matters.

3. It secures the rapid removal of all excretal and household sewage in a manner to satisfy the requirements of health and economy, and in a condition to render its subsequent utilization as a manure not only possible, but easy of accomplishment.

The weight of testimony against the water-carriage system, or the "*tout a l'egout*," and in favor of a special canalization for putrefying household wastes is so overwhelming that nothing in fact could be more conclusive as to the evils of the one and the value of the other.

In 1860 Victor Hugo, who has enriched literature with so many great works, published a book, entitled "Les Miserables," in which the following passage occurs:

"Paris casts twenty-five millions of francs annually into "the sea. * * * * Twenty-five millions are the most mod- "erate of the approximative amounts given by the estimates of "modern science. Science, after groping for a long time, knows "now that the most fertilizing and effective of manures is "human manure. The Chinese knew this before we did; not a "Chinese peasant who goes to the city but brings at either end "of his bamboo a bucket full of what we call filth. Thanks to "the human manure the soil in China is still as youthful as in "the days of Abraham, and Chinese wheat yields just one hun- "dred and twenty fold the sowing. There is no guano compar- "able in fertility to the detritus of a city. To employ the town "in manuring the plain would be certain success, for if gold be "dross, on the other hand our dross is gold.

"What is done with this golden dung? It is swept into the "gulf. We send, at a great expense, fleets of ships to collect at "the Southern pole the guano of petrels and penguins, and cast "into the sea the incalculable element of wealth which we have "under our hand. All the human and animal manure which "the world loses, if returned to the land, instead of being thrown "into the sea, would suffice to nourish the world. * * * * "Statistics have calculated that France alone pours every year "into the Atlantic five hundred millions. The cleverness of "man is so great that he prefers to get rid of these five hundred "millions in the gutter. The very substance of the people is "borne away, here drop by drop, and there in streams, by the "wretched vomiting of our sewers into the rivers, and the "gigantic vomiting of our rivers into the ocean. Each eructa- "tion of our drains costs us one thousand francs, and this has "two results: the earth impoverished and the water poisoned; "hunger issuing from the furrow and illness from the river. It "is notorious that at this very hour the Thames poisons London! "and, as regards Paris, it has been found necessary to remove "most of the mouths of the sewers down the river below the last "bridge.

"* * * * The present process does mischief, while mean- "ing well. The intention is good, but the result is sorrowful; "they believe they are draining the city, while they are destroy- "ing the population. A sewer is a misunderstanding, and when "drainage, with its double functions, restoring what it takes, is "everywhere substituted for the sewer (that simple and impov- "erishing washing), and is also combined with the data of a "new social economy, the produce of the soil will be increased "ten-fold, and the problem of misery will be singularly attenu- "ated."

Belgrand, Chief Engineer and Director of the Paris Water Works, reflecting upon the words of Victor Hugo, said in 1861: "On the principle of cesspool emptying. there is but one opinion. "We must have for Paris a well defined plan. The excretal "sewage of the city should be conveyed away by a *special tube* "circulating under the city and sent to a distance to be treated "and disposed of for agricultural purposes."

Inspired by this idea, Baron Haussmann, Prefect of the Seine, in the same year wrote: "I have thought of a radical combina- "tion that will do away with the privy sinks or cesspools, viz., "a net work of pipes leading into a special pipe and large enough "not to get choked up. Room will be found for the latter in the "sewer galleries, and the whole system to be subjected to the "action of *double-acting* engines, by which the excretal sewage "may be gathered into distant tanks, and be subsequently treated "by some process that will convert it into a material suitable "for agricultural purposes."

"The drains of Rome absorbed the entire welfare of the "Roman peasant. When the Campagna of Rome was ruined "by the Roman drains, Rome exhausted Italy, and when it had "placed Italy in its cloaca, it poured into it Sicily, and then Sar- "dinia, and then Africa. The drains of Rome swallowed up the "world, and this cloaca offered its tunnels to the city and to the "world. *Urbi et orbi.* Eternal city and unfathomable drain."—*Liebig.*

"I would never have assumed the responsibility of a meas- "ure that might create centres of putrefaction about Paris. It "would be wise not to mix the fæcal matter with the sewer "water."—*Pasteur.*

M. Alphand, Inspector of Bridges and Roads, Director of the Public Works of Paris, Director of the Universal Exhibition to be held in Paris in 1889, in his inaugural address to the Superior Sanitary Commission, appointed to suggest measures for the better sanitation of Paris, indicated the prominent points of his programme on that question as follows:

"Immediate removal of all excretal matters from the houses "by special pipes for conveying the matter beyond the limits of "the city in the shortest time possible."

M. Conche, Chief Engineer of the Health Department of Paris, in his report of the 20th July, 1883, says: "It cannot be "denied that the process of removing excreta by means of *closed* "*canals* from centers of population presents a real superiority "over all other systems."

Prof. Brouardel, member of the Faculty of Paris, President of the Committee of Consultation of Public Hygiene of France, member of the *Commission de l'assinissement de Paris*, &c., &c.,

says: "For excretal sewage a definite system should be adopted, "by which excrementitious matter will be received directly "from the closets into absolutely *air-tight metallic pipes* without "any communication with either the atmosphere or the soil, "which pipes will convey the matter rapidly from the city to a "point where it may be transformed into a dry manure powder. "This system should be operated by *double-acting pumps*, and the "sewage conveyed *in vacuo*."

"The only system the Commission can approve is that of "emptying the cesspools by means of an air-tight canalization, "which will prevent all communication between the excremen-"titious matters on the one side and the surrounding soil on the "other."—*Committee of Consultation on the Public Hygiene of France*, 1880.

"The pneumatic removal of excretal sewage is the only "solution of the question, so far as hygiene is concerned."—*De Mussy's Report on School Hygiene.*

M. Dumas, the eminent French chemist (member of the Academy of Sciences, France), in speaking of the pneumatic system proposed for Paris, says: "By its arterial system Paris "receives pure water; by a proper veinous system it would "restore to the earth all the elements necessary for fertilization, "and to the river a filtered water deprived of all principles of "corruption."

M. Marie Davy, Director of the Paris Observatory, in a communication to the French Society of Hygiene (*Journal d' Hygiene,* April 27th, 1882), says: "For the hygienist who "submits to the logic of the *absolute*, all fluids containing azotic "matter, that may become putrid, must be removed by a special "metallic canalization, among which are comprised fæcal mat-"ters, slops, water from public urinals, workshops," etc.

At a recent meeting of the French Society of Public Medicine and Professional Hygiene, Dr. Henri Napias, secretary, said: "The administration will have to estimate the cost of "constructing a special canalization for fæcal matters; the "hygienists will reserve to themselves the right of counting the "number of premature deaths, both useless and unjustifiable, "due to defective conditions of sanitation, and then the balance "may be drawn."

"After a few years you must adopt the pneumatic system. "Why not adopt it now? It is the only system which fulfills "the requirements of sanitarians."—*Dr. Levrand.*

In his report to the Borda Society on the "Underground "Hygiene of Cities," Dr. Mora expresses himself as follows: "In fact, the pneumatic aspiration of excrements withdraws "the infectious elements, either typhoidal or other, from all "contact or mixture with the air; it substitutes a better method "for emptying closets than that of the cesspit system, which is "so noxious and unpleasant, and it contributes largely to lessen "outbreaks of typhoid fever, cholera, &c."

"A large town ought to possess a special canalization for "fresh water; an air-tight net-work of sewers to carry off excre- "tal and household wastes, as rapidly as they are formed."—*Report Sanitary Congress, Geneva, Switzerland.*

"The best system, according to our judgment, is one by "which excremental matter of every description is removed in "air-tight pipes as it is produced to one or more central stations "for treatment."—*Report of the Special Commission of Hygiene of Belgium*, 1886.

"An air-tight metallic canalization intended to carry all the "dejections, including public urinals, would be the desired "thing."—*Journal La Ville de Paris.*

Mr. Edmond About, in the *Nineteenth Century*, Paris, September, 1884, in speaking of the proposed pneumatic system, says: "We approve most heartily of the conclusions of the Commis- "sion, and should their recommendations be adopted by the

"Municipal Council, for once, for ever, we shall get rid of those "infectious matters which poison the streets and houses of "Paris."

The leading principle of pneumatic systems is the employment of two distinct sets of sewers; the one for matters which are essentially dangerous from a sanitary standpoint, but have sufficient manurial value to justify the adoption of such processes as would render them available for agricultural purposes; the other for storm water, which can be discharged directly into the nearest water-course.

In the first set of sewers small pipes are used, the moving force being that of "æro-dynamics," or air pressure instead of water. This pressure is exerted the moment the air of any hermetically closed vessel is wholly or partially removed. A vacuum being created, the outer air endeavors, as it were, to *get in*, or fill the vessel, and in doing so exerts a pressure upon the surface proportionate to the degree of vacuity within. Now, if one end of a tube should stand in communication with a vacuum and the other end in communication with the open air, this pressure would be, of course, equally exerted upon any movable substance within the tube, and the substance or body would be forced by the air towards the vacuum; or, in other words, it would be drawn into the vacuum by the action vulgarly known as "suction."

Such sucking force will be exerted by any reservoir deprived of air, upon any pipe connected with it; and any fluid within the pipe, filling its cross-section, will be drawn towards the reservoir with a force proportionate to the difference of the air pressure on the two ends of the pipe, and the speed of motion so produced will be proportionate to the frictional resistance with which the fluid meets and the force exerted upon it.

These well-known physical laws are made use of for the removal of fæcal and other putrescible matters;

1. Because aspirating force prevents *eo ipso* every escape of deleterious matter from any vessel containing such matter, be it solid, fluid, or gaseous. The only effect of a leak would be the rushing *in* of atmospheric air, earth or water, or whatever medium the vessel might be surrounded by. Pollution of air, soil or water would, therefore, be absolutely impossible.

2. Because by employing aspirating force the gaseous products of putrescible matter can be removed at one and the same time with the matter itself, thus making their destruction by means of burning practically possible.

3. Because by employing aspirating force no dilution of the matter to be removed takes place, which can either lessen its manurial value or increase its bulk.

The object of the pneumatic system is the removal of dangerous sewage matters, especially excretal sewage, from towns or centres of population, to some convenient point outside the town, in a rapid and scentless manner, by means of iron pipes in which a vacuum, to a certain degree, is maintained, and without the excessive dilution caused by water-carriage, which renders the sewage quite valueless as an agricultural agent; or, at least, greatly increases the difficulty and expense of manufacturing a dry manure from it.

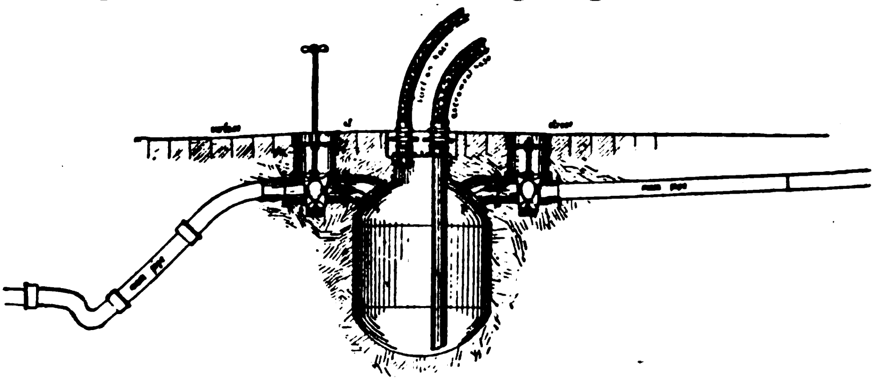
Several systems of the kind have been proposed, which in principle are all in harmony with M. Belgrand's suggestion. The first was brought to the attention of the public by Captain Charles T. Liernur, a Dutch engineer, in 1872; the second by Mr. Isaac Shone, a mining and civil engineer, of Wrexham, Wales, in 1878; a third by Monsieur J. B. Berlier, Civil Engineer and Director of Sewerage Works at Lyons, France, in 1881; and a fourth by M. Adrian Le Marquand, Civil Engineer of Paris, in the present year.

CHAPTER XXI.

The Differentiating Pneumatic System of Liernur.

THE differentiating system of Captain Charles T. Liernur was described by me in a paper read before the Medical and Chirurgical Faculty of Maryland in April, 1883, as follows:

" At the crossing of two or more main streets is placed " under the pavement an air-tight cast-iron cylinder-shaped " reservoir of about five feet in diameter and fifteen or twenty " feet long, as shown in the following diagram:



" From this reservoir as a centre is run iron pipes along the " streets leading to the crossing, these pipes being the 'street- " mains' for conducting the fæcal, stable, manufacturing and " other sewage matters out of the houses into the reservoir.

" Each street-main receives as many branch pipes as there " may be houses right and left, and is shut off from the reservoir " by means of an ordinary stop-cock. The air being exhausted " and the street-main cock opened, the reservoir will exert a " powerful sucking force upon all the branches of the street-main, " and the consequence will be that whatever fluid matter any " trap, sink or gully of these branch pipes may contain will be " forced or sucked into the reservoir as if driven by a tornado.

"A minute or two suffices to remove in this manner the "fæcal and other putrescible matters from all the houses of a "street of half a mile in length. This being accomplished in "one street, another, connected with the same reservoir, is taken "in hand, and thus each street of the crossing is worked in turn "until the process is extended to the whole district. The reser- "voir serving as the drainage centre of a district will contain all "the putrescible matter of that district up to a certain point, "when it is emptied by a process to be hereafter described.

"The rapid performance above referred to is due to the simul- "taneous action of the branch pipes of the same street-main, "which takes place notwithstanding the great difference which "may exist in the quantity of matter they contain.

"At first view it would seem that on applying an equally "great suction to all the pipes, the one containing the smallest "quantity of matter, and consequently offering the least amount "of resistance, would be emptied first, thus destroying the "vacuum in the street-main, and preventing thereby the other "branch pipes being emptied at all. This is prevented, how- "ever, by a simple contrivance.

"The branch-pipes are converted, as it were, into so many "barometers by simply giving them slight bends, so that their "contents become subject to the same law which governs "barometric columns of fluid matter. The branch pipes being, "by means of the common street-mains to which they belong, "connected with the same vacuum, this exerts the same force "on the different hydraulic heights of fluid in the two shanks "of each bend; and all bends having the same height, the "maximum and minimum resistance or lift of fluid matter to "be overcome will be in all the pipes the same. Now, it is well "known that in barometers the maximum resistance of lift "occurs when one of the shanks is entirely empty, and that the "minimum lift (*i. e.* none at all) occurs when the fluid in both "shanks stands on a level, one column holding, as it were, the "other in balance. This will be equally the case when one of "the shanks stands vertical and the other has an inclined posi- "tion of—say, 1 in 40, so that the bulk of fluid matter holding "the other in balance is forty times greater. The bends of the "branch pipes are, therefore, formed so as to have one shank "inclined and the other upright, so that any branch pipe stand- "ing entirely full and 41 quantities of the size of the short "shank, offers to a vacuum connected with the latter no resist- "ance of lift whatever. Hence the one containing the most "fluid matter begins, after turning on the vacuum, to empty "itself first, and continues to do so until its contents are reduced "to that of some other branch pipe holding an equal quantity, "which thereupon—the resistance of lift being the same—starts "to emptying itself also. These two will continue to work "together until their contents are reduced to that of other "branch pipes which, in turn, are brought into action. In this "manner more and more of the pipes become engaged, until at "length the maximum lift, due to the minimum quantity of the "short vertical shank, is reached in all the pipes.

"It is in this way that the simultaneous action above men- "tioned takes place The atmospheric air rushing in through "all the branch pipes at once hurls the fluid, broken up into "particles with great violence through the street-main into the "reservoir.

"This rushing in of air does not, of course, take place "through the closets, but through the fall-pipe into which they "empty, this pipe being extended above the roof.

"The city is divided into districts of from 20 to 40 acres area, "and each district is provided with a reservoir for its pneumatic "drainage centre. The various districts are, therefore, worked "independently of each other, and any accident to the works of "one district does not affect those of another district.

"It remains now to be explained how these various district "reservoirs are supplied with vacuum power, how the matter "collected in them is removed, and what is done with it after it "reaches the point of destination.

"At some convenient point outside of the city, air pumps "driven by steam power are erected to maintain a vacuum of "¾ atmospheres in two large air-tight tanks. From these tanks "a line of piping runs centrally through the city along some of "its main streets, connecting the tanks with the district reser-"voirs either directly or by means of short branches. This line "of piping is called the 'vacuum main,' and the ¾ vacuum just "mentioned is maintained uninterruptedly both in the vacuum "main and the central tanks, day and night.

"At any time, therefore, that a connecting cock between "the vacuum main and any district reservoir is opened, a "vacuum of nearly ¾ atmospheres will be obtained in the latter, "the air of the reservoir escaping into the vacuum main.

"Parallel with the vacuum main and along its entire "length lies another line of piping called the 'transport main,' "which serves for conveying the fæcal matters collected in the "district reservoirs to the pumping station. The forwarding of "this matter is also effected by aspiration, there being at inter-"vals of about a mile arrangements for placing at will the "transport main in communication either with the vacuum "main or with the open air.

"In order to discharge the reservoirs into the transport "main the latter is furnished with branches reaching to the "bottom of the former. To 'forward' the fæcal contents of "any one of the reservoirs to the pumping station it is only "necessary to open the vacuum cock of the transport main of "the intermediate station ahead. The contents of the reservoir "will then at once empty into the transport main, forming in "it a column of some 100 or 200 yards in length, with a speed "of from 12 to 18 feet per second, depending upon the length "of the column and the degree of vacuum Before the head of "the column has reached the open vacuum cock another farther "ahead is opened, so that the speed remains unimpaired, and "the cock, until then opened, is now closed. The moment the "end of the column has passed this point the transport main "itself is shut off after it and atmospheric air admitted, the "driving force being thus in its turn renewed.

"In this manner the column of fæcal matter flies along its "way from station to station without ever slackening speed "or stopping on the route, the various stretches of transport "main being shut off after it as soon as it has passed, thus "allowing the route passed over to be used again for for-"warding other columns immediately after.

"It appears from this that the distances to which fæcal "matter or other sewage matter can be transported subter-"raneously are practically without limit, as the moving agency "is renewed every time a certain distance is accomplished.

"The distance to which a vacuum can be carried without "losing power enough to become a matter of importance is also "practically unlimited. This is evidenced by the well-known "fact that the pressure of a couple of feet of water suffices to "send light gases through pipes from one end to another of "the largest cities, although the pipes attain at length a very "small bore; and as the frictional resistance of gases in pipes "increases or diminishes in the ratio of their pressure or "tension, and as a $\frac{3}{4}$ vacuum exerts less than $\frac{1}{4}$ of the pressure "of light gas, it is clear that such a vacuum can be maintained "at least *four times farther* than light gas could be conveyed, "without consuming more force than is measured by the "pressure of two feet of water in about $\frac{1}{16}$ atmospheres.

"The system is, therefore, equally applicable to large cities "or small towns, the only difference in the constructive details "of the arrangements being that the number of districts to "be sewered and the number of stretches of transport main "are greater for large places.

"In the first works of the kind constructed the various stop-"cocks mentioned above were operated by hand, an attendant "going for the purpose from one district reservoir to another, and "serving in this manner some fifteen or twenty per day, whilst "two others attended to the forwarding business. With this "view the cocks connecting the street mains with the district "reservoirs and those of the transport main were so arranged "that they could be worked from the street by means of a "lever or key. But this primitive mode of operating the "apparatus has been superseded by a more convenient and "perfect method.

"The district reservoirs are placed in subterraneous cham-"bers, in which the various cocks for working the street mains "are grouped together and operated by simple clock-work, regu-"lated, like most clocks, by a pendulum. This clock turns a "small cylinder armed with studs or points, like the cylinder of "a music box, which press at fixed periods upon small keys like "those of a piano. These keys communicate with small valves "either admitting air or occasioning a vacuum, as the case may "be, in vertical cylinders of about six inches bore and ten "inches stroke, the pistons of which open the various street-"main cocks suddenly and with great force just at the required "moment. The clock is worked by a simple spiral spring, "having only to turn the cylinder or drum, but it is connected "with a diminutive vacuum engine operated from the vacuum "main, which winds up the spring of the clock as fast as it "runs down, thus making the whole arrangement not only "self-acting, but also self-governing and continual, inasmuch "as the vacuum of the vacuum main, serving as a motive "power for the whole contrivance, is uninterruptedly kept up "day and night.

"The system, therefore, needs no other manual service "than is necessary to attend the engines at the central or gen- "eral pumping station. The reservoir chambers containing this "operating apparatus are accessible from the streets or side- "walks for occasional inspection."—*Proceedings of the Medical and Chirurgical Faculty of Maryland, 1883.*

At the time of my investigation of the Liernur system, at Amsterdam, in 1883, the central building or general receiving station was not completed, and the street tanks were emptied by a small portable engine, the contents being barrelled and removed as a liquid manure by boats. It was then represented that when the central building was completed a steam engine operating an air pump would produce a vacuum in the large reservoirs, and in the main pipes connected with them, which pipes were to connect with the street reservoirs, and draw the sewage matter contained in them to the central station by pneumatic suction, where it would be rapidly evaporated to dryness by means of super-heated steam and special machinery, the product being a dry manure powder, which it was claimed would represent an agriculture value of from $40 to $50 per cubic metre (ten), as there would be no loss of organic or inorganic matters in the process of evaporation. The expense of the service in the three principal districts of the city, with an aggregate population of twenty-three thousand two hundred and thirty-nine people, was given in the report of the Chief Engineer for 1882, at $2,326.61, less amount paid by house owners for cleaning house pipes $95.90, making the net $2,230.71, or only about ten cents per inhabitant per year, which it was stated would be notably reduced when the various districts were joined to the central station, then in course of construction. The central building with its machinery, including engines, air pumps, reservoirs, drying drums, &c., has been completed and the several district reservoirs are now connected with it; but, I must in candor state, that great disappointment has been experienced, both as to the efficacy or power of the pneumatic suction, and the commercial value of the *poudrette*, as will be seen by the following letter from Mr. Ch. R. Kouveld, Civil Engineer, of Amsterdam:

AMSTERDAM, December 20th, 1886.

C. W. CHANCELLOR, M. D., Esq.,

76 *Ave. Victor Hugo, Paris, France.*

MY DEAR SIR—In reply to your favor of the 16th inst., I beg to say that I shall be very glad to be of any service to you.

The success of Capt. Liernur's system in this city is yet very problematical. In his original system he planned two lines of pipes for every house,—one for the waste-water, the other for excretal matters. This made the system rather expensive, and he abandoned the waste-water pipe with the result that this water is now almost entirely discharged with the excreta. It is hardly necessary to point out how unfavorably this influences the result. At the central pumping stations there arrives a liquid almost valueless. An effort has been made to evaporate the water and condense the matter, for which an apparatus was made similar to the "triple effet" apparatus in sugar works, but it proved a failure in consequence of the matter adhering to the sides of the apparatus. This is, however, a technical difficulty which may be surmounted; but, what is worse, the condensed matter, which costs so much fuel to bring it to the desired state of dryness, possesses but little value as a manure, and at this time the excretal matters which arrive at the central pumping station are allowed to flow away, and are not utilized in any way. The system, moreover, has proved to be more expensive than was anticipated, owing to the great number of technical difficulties which had not been foreseen, but which have handicapped the system very severely. The cost of working it (which had been placed at less than 10 American cents per head per annum) is now 59 Dutch cents, equal to very nearly 24 American cents per head, in the districts of the city where the system is applied.

It appears also that the Central Pumping Station does not work satisfactorily in the parts of the city it was intended to, so that one of the former small pumping stations, which was to have been done away with after the erection of the Central Pumping Station is now actually working a district of the town, the central pumps not being able to suck the material through the pipes laid upon a bridge over the river Amstel, which runs between the district and the central station.

If you should need further particulars, and will formulate your wishes in a series of questions, I will endeavor to answer them satisfactorily. For a thorough study of the system as it actually exists, however, it is almost indispensable that you should see it yourself, because so many changes and alterations have been made, influenced by local difficulties, that it is quite impossible to speak of them intelligibly. The experience had with the system here inclines me to the belief that it would not answer well in any city with an undulating surface, and that it can only be applied in places where there are no considerable elevations.

I remain, dear sir,

Yours faithfully,

CH. R. KOUVELD.

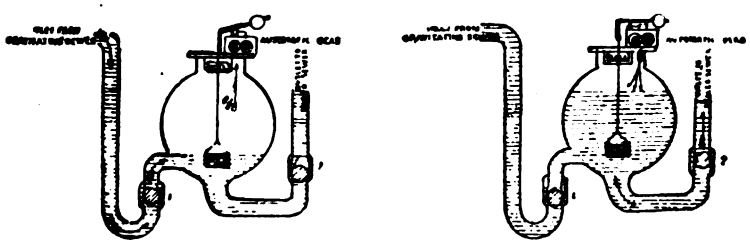
CHAPTER XXII.

THE SHONE SYSTEM.

THIS is a method of pumping sewage by the direct action of compressed air, invented by Mr. Isaac Shone, of Wrexham, Wales.

"In applying this system to a city or town, the house "drainage, comprising excreta and all liquid wastes, is conducted "by gravity to a low point in each drainage district, through "ordinary sewers, in which nothing else is permitted to flow.

"At each of these points is situated a 'pneumatic injector,' "into which the sewage flows, and by which it is raised, by the "direct pressure of compressed air, to any required height, into "a system of cast-iron pipes, jointed like water pipes, in which "the sewage is forced to the point of discharge.



PNEUMATIC INJECTORS.

"The air which forms the motive power of all the injectors "is compressed at some convenient place by a compressor "operated by steam or water power. Hence the compressed air

" is supplied to the ejectors through small iron pipes laid through " the streets."—*Report of Messrs. Gray and Swan*, 1884.

There is, we need scarcely say, great diversity of opinion as to the efficiency of this system, and the economy with which it can be carried out.

CHAPTER XXIII.

The Berlier Pneumatic System.

MR. ADAM SMITH, Corresponding Member of the Society of Medicine and Public Hygiene, of Paris; correspondent of the London *Lancet*, &c., has, in an octavo pamphlet of fifty pages, supplied us with the technical details necessary to the full understanding of the Berlier system, from which the following is extracted:

" In the year 1878, Monsieur J. B. Berlier, Civil Engineer, " and Director (at that time) of the Sewage Works of Lyons, " published a pamphlet, in which he exposed a scheme of town " drainage which, in its broad principle, was in harmony with " M. Belgrand's suggestion. He proposed a metallic canalization " working by means of a pneumatic pump, which was to be " placed either within the sewers, or along trenches, or even " gutters. These pipes would, of course, be absolutely air-tight— " their contents would never come into contact with the external " atmosphere, or the surrounding land.

" The necessity of some new and more effective method of " drainage had made itself more particularly felt at Lyons in " 1874, when a very virulent outbreak of typhoid fever devastated " the town. The epidemic was attributed to the infection of the

" sewers by certain houses that drained direct into them. It
" was also the custom to empty the contents carted away from
" the cesspools into barges moored in the Rhone. This process
" gave rise to such a nuisance that the habitations near the river
" side became notoriously unwholesome. Fortunately M. Ber-
" lier's position as Director of the *Compagnie des Vidanges et*
" *Engrais de Lyon*, enabled him to make experiments which
" otherwise could not easily have been attempted. Public
" opinion also, alarmed by the fears of epidemics, gave addi-
" tional sanction to his innovations.

" In May, 1880, he commenced an underground canalization,
" which put an end to the necessity of conveying the contents of
" the cesspools to the barges on the Rhone. In November these
" works were completed, and ever since that date these iron pipes
" have every day, without interruption or accident, conveyed to
" a distance of 4 kilometres (2½ miles) the sewage of Lyons. The
" Prefect of the Rhone, seeing the importance of the results thus
" obtained, demanded that a Commission should be appointed to
" draw up an official report on the subject. This Commission
" was composed of :—

M. DELOCRE, Chief Engineer of the Ponts et Chaussées in charge of the services of the department.

M. DOMENGET, Chief Engineer of the Ponts et Chaussées, Director of Municipal Ways and Roads Service.

M. GLENARD, President of the Council of Hygiene.

M. LOIR, Senior Member of the Faculty of Sciences.

M. SORTET, Senior Member of the Faculty of Medicine.

M. FERRAUD, Chemist, Member of the Council of Hygiene.

It would require too much space to give the full results of this inquiry, but the following are the concluding paragraphs of the report:

" The possibility of draining and drawing liquid sewage from one distant point to another by means of iron pipes, in which vacuum to a certain degree is maintained, can, considering the results obtained by M. Berlier, be now no longer contested. It is even demonstrated that this result can be obtained with great facility and economy.

"The installation made by M. Berlier is imperfect, because it was only an experiment, and the engineers did not agree as to the possibility of success. * * * It would, therefore, not be impossible to extend the canalization to the various quarters of the town of Lyons, where mouths for the emptying of sewage would be established, similar to those for carrying away storm water. This would facilitate greatly the emptying of the cesspools, and would cause much less inconvenience to the population.

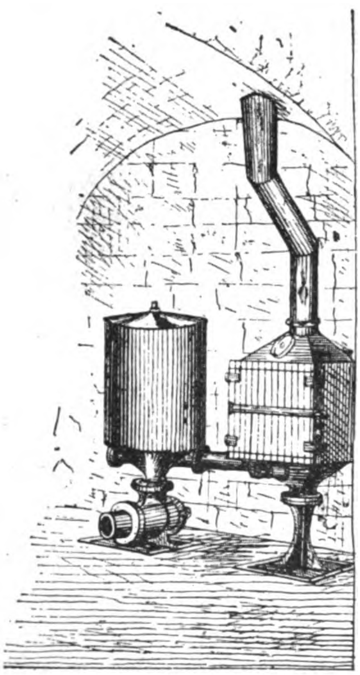
"To sum up, the Commission considers that the experiments made by M. Berlier may lead to the most important consequences, aud may be the basis of very great ameliorations in the draining of towns."

The Lyons experiment is, however, of comparatively little importance when compared to what has since been done in Paris. It only related to the removal of sewage when that sewage, after the emptying of a cesspool, had been accumulated at a given point. In Paris, cesspools are done away with altogether wherever the Berlier system is applied; and now the experiment at Lyons has no further interest than that of demonstrating how easily the sewage travels along small pipes when drawn forward by pneumatic suction.

M. Berlier submitted a scheme for the draining of Paris to the Muncipal Council in 1881, and after reference to the Sewer Commissioners he was authorized, in the month of August of that year, to make experiments throughout the district extending from Levallois-Perret to the Madeleine.

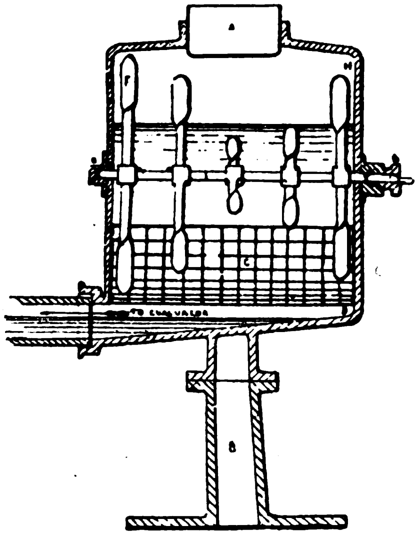
The main sewers from Levallois-Perret to the Place de la Concorde are large, commodious underground passages, with a ledge where M. Berlier's iron tubes find an appropriate resting place; but it was necessary to make four dips or syphons, so as to pass under obstacles in the way of the tubes. The first of these occurs in passing under the sewer of the Rue Rivoli; the other three are due to dams established at Levallois-Perret, the last being close to the pumping station itself. The latter syphon connects with the reservoir constructed at the pumping station for the reception of the sewage, and this at an elevation of 60 centimetres (24 inches) above the average height of the pipes placed on the ledge of the main sewer.

Before, however, we continue to further describe this vast canalization, it is necessary that we should explain how the connection with the house is established; for in this consists the special ingenuity of the Berlier system. It is obvious that no solid hard substance can with safety be admitted into such small pipes; yet, in France especially, great carelessness is displayed as to what is thrown down drain pipes. In America we are not without reproach in this respect. Nevertheless, the existence of a syphon trap under the pan of most closets, and the small dimensions of the drain pipe (rarely larger than four inches in diameter) give rise so promptly to obstructions that we are becoming more careful. In Paris, however, there are no traps. Sometimes there is not even a valve to the pan of the closet, and the pipes are never less than six inches, and often even eight inches in diameter. They are made both large and straight on purpose to prevent obstruction when the housemaid, in her ill humors, throws duster and brush down the drain. Against these various circumstances it was necessary to take special precautions, and hence M. Berlier has devised a suitable apparatus, consisting of two parts, a 'Receiver' and an 'Evacuator.'



The *Receiver* is a rectangular-shaped iron vessel. It is placed under the house drain pipe, immediately below the closets if possible. The house drainage, conveyed by drain pipes actually in existence, whatever their size or the nature of the closets above, all converge and fall into the *receiver*. Within there is an iron wire-work circular basket, measuring 425 centimetres in diameter, while the *receiver* itself is 550 centimetres square, and a metre in depth. All hard substances and foreign bodies are retained in the wire-work basket. Once a week a man in the employ of the Administration visits these *receivers*, and by means of a removable handle, to be affixed from the outside, imparts to the basket a violent rotary motion. The presence of a brush or heavy body is at once detected by the noise it makes when the basket is set in motion. The *receiver* can then at once be opened and the foreign body withdrawn. Also any soluble though somewhat hard substance, when beaten about by the motion of the basket, is soon sufficiently broken up to pass through the wire-work that surrounds it. Hence, whatever leaves the basket is in a fit condition to travel along the iron pipes without giving rise to any danger of obstruction. This is the sole purpose and function of the *receiver*. It must be understood that this filtering process is of a very coarse character, that it admits of the ready passage of all night soil, and is really only intended to withhold foreign bodies. The wires of the strainer are more than an inch apart. It would not be judicious, from a health point of view, to retain within this basket for some days the solid portion of the sewerage Therefore, what with the pressure and current of water, its natural dissolving tendency, and the largeness of the space between the wires, everything that should not be withheld passes readily away in at least a semi-liquid condition. The basket itself can be easily lifted right out of the case, if desired, either for cleaning purposes or for repairs. It is not necessary to describe the simple mechanism that imparts a centrifugal and powerful rotary motion to the strainer, as any mechanic will at once understand that this result can be easily attained.

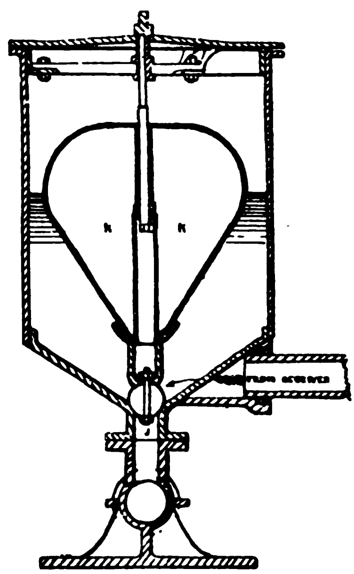
Such are the *receivers* which up to this date have been in use, and, though they have served their purpose very well, a new model has just been invented. As it will be seen, by the accompanying illustration, the principle is the same, though the means employed to carry it out are very different. The drawing represents a vertical and longitudinal cut of the apparatus.



RECEIVER.

Instead of a circular basket in the *receiver*, there is a double bottom, the first being of wire work on supports. This acts as a strainer. A slight inclination enables the contents of the apparatus to gravitate towards the mouth or outfall. Above the strainer are a number of beaters, to which a rotary motion is imparted from the outside. These, like the screw of a steamer, beat the water, macerate and dilute solid substances. These arms of graduated length dip down nearer and nearer to the strainer as they approach the outfall, thus the hard substances experience a progressive compression as they get closer to the point of exit. By this means the danger of obstruction is further minimized.

The *Evacuator* is a second apparatus which serves to disconnect the house drainage from the public drainage, though it conveys the one to the other. It is placed side by side with the *receiver*, is also made of iron, and of about the same size, though circular in



EVACUATOR.

shape. The night soil, rendered liquid by its passage through the wire-work basket, runs by gravitation from the *receiver* into the *evacuator*. Here is placed a large ovoid floater, the broadest portion being 450 centimetres in diameter, though the diameter of the cylinder itself is only 550 centimetres. The base of the *evacuator* is of cone-like shape, while the point of the floater is armed with an India-rubber valve that fits hermetically the opening at the bottom. This opening communicates with the tubes in which the partial vacuum is maintained, and the pneumatic suction helps to maintain the floater firmly fixed and drawn down upon the mouth of the apparatus. When, however, a sufficient quantity of liquid has accumulated in the *evacuator*, the buoyancy of the floater proves stronger than the downward suction. Disengaging itself at last, the floater springs upwards, and the pneumatic suction, now acting on the liquids, rapidly draws them away. The difference of pressure of atmosphere between the interior of the pipes and of the *evacuator* is sufficient to ensure the prompt removal of all the liquids. When no longer supported by the water the floater falls back on the aperture without allowing any passage of air. This operation renews itself automatically each time the liquids reach the floating line of the apparatus. In all this there is no complicated machinery, nothing apt to get out of order. Since the 17th of March, 1881, when these *receivers* and *evacuators* were placed at the Pépinière barracks they have worked regularly, automatically, and without any accident. As the water leaves the *evacuator* the ovoid floater experiences a certain oscillation. It rises and falls once or twice before finally fixing itself in its resting place. This oscillation, due to the movement of all liquids within the apparatus, has its use in firmly fixing the valve. This being of India-rubber, retained in its centre by an iron bar, forces itself well into the mouth of the *evacuator*, which it closes hermetically. These two apparatus, the *receiver* and the *evacuator*, may, therefore, be placed anywhere, either in a cellar, in a cupboard, underneath the staircase, without the slightest fear of any nuisance arising. Apart from being air-tight in themselves, the gas from the tubes cannot possibly enter them. The fresh night soil they contain remains for so short a period within them that it has not time to ferment, and when, for the purpose of examination, several *receivers* were opened, we noticed no unpleasantness.

The sewerage travels along the iron tubes with the greatest facility. The vacuum to be maintained in this canalization need not exceed a barometric pressure of 150 m.m., and this can most easily be obtained. During the whole of the journey the semi-solids are held in suspension, as if something was constantly stirring up the water inside the pipes. This peculiarity has the appearance of ebullition, and is produced by the movement of the air within the pipes as it is drawn forward by the pump at the works. Also, the reduction of pressure produces a certain amount of evaporation. Thus the deposits that invariably take place in all other pipes or sewers are prevented. The sewage being charged with gas that bubbles up and keeps all the more or less heavy matter in suspension, it is readily carried along and does not adhere to the sides of the tubes.

For this same reason syphons do not give rise to the customary risk of stoppage. In ordinary cases the gases accumulating at the upper portion of the syphon press downward and render it difficult for the water to rise. With pneumatic suction no such hindrance can take place. The air bulbs change in shape, they become ovoid, spherical, etc., while passing through the syphon, but their progress is not impeded. The aspiration is so thorough, so completely to be relied upon, that it is even suggested to employ it for the ventilation of the closets. It is proposed to contrive a slight opening in the pan of such closets which, when the closet is in use, would draw away from the pan all the surrounding atmosphere, and thus prevent any unpleasantness.

The pumping stations where the vacuum is produced in the pipes are also managed so that they could be situated even in the centre of a town without occasioning any inconvenience. The foul gases aspired are at once pumped forward into a pipe that conveys them away to the sewerage works where the ammoniacal products are made. All this is done under cover. There is no communication with the outer air, and no escape of gas possible.

The pipes or tubes in the main sewers measure six inches in diameter, but those that run up the neighboring streets are only four inches in diameter. The first branch of this descripiton is that in the rue de la Pépinière, and it has a syphon passing under the entrance to the sewer. It is by this pipe that all the night soil from the Pépinière barracks, containing one thousand men, is drawn away, thus showing how the system works on a large scale and when applied to the requirements of a great agglomeration of persons. On the other hand, we find the system working for private houses in the rue Royale, in the rue du Rocher, in the rue de la Bienfaisance, and in the Boulevard Malesherbes, at the public closet or *chalet* of the Place de la Madeleine, and the following railroad stations, viz.: The Paris, Lyon & Marseille, the Orleans, the Western, and several others; also at the Magasin du Printemps, the Central Gas Company, the Department of the Ministere de la Marine, &c., &c. Thus the pipes already established in Paris extend over seven miles, drain both public and private buildings, have to form a curve so as to pass under obstacles that bar their passage, and encounter in their course all the difficulties that might be anticipated in any large undertaking of this nature.

The following figures indicate theoretically the results of the system, so far as it has been tested in the Eighth and Ninth wards of Paris:

Matter extracted		in 24 hours	300 cubic metres.
"	"	in 1 hour	12.5 " "
"	"	in 1 minute	208 litres.
"	"	in 1 second	3.40 "
Diameter of collector arriving at works			150 millimetres.

Three hundred cubic metres (tons) of diluted matter arriving daily at the central station at Levallois-Perret is far greater than could be effected by water-carriage through the same diameter pipes.

The following testimonials as to the efficiency of the system, in a hygienic point of view, should attract the attention of all sanitarians.

TESTIMONIALS.

"*Resolved*, By the Municipal Council of Paris, that the Prefect of the Seine be requested to authorize the *Compagnie Generale de Salubrite* to extend the trial of the Berlier's pneumatic system."—November 16th, 1883.

LETTER FROM GENERAL LEVY.

MILITARY GOVERNMENT OF PARIS, ENGINEERS' DEPARTMENT.

PARIS, 2d October, 1882.

The General Director of the Engineers' Department at Paris certifies that the experiments at the Pépinière Barracks authorized by the Minister of War, and begun on the 17th of March, 1882, and continued up to this time by M. Berlier with his pneumatic system of sewage, have given very good results. The apparatus has worked well and without interruption all the time.

(Signed) LEVY, *General.*

FROM THE CHIEF OF ENGINEERS OF PARIS.

The Major, Chief of Engineers of Paris (right bank) certifies that the application at the Pépinière Barracks, of Berlier's pneumatic-sewage system, has given excellent results in every respect, and that the apparatus has worked perfectly without stopping since it started.

PARIS, 15th January, 1886.

(Signed) DERENDINGER, *Commandant.*

FROM THE P., L. & M. RAILWAY COMPANY.

The Paris, Lyon and Mediterranean Railway Company certify that Berlier's pneumatic-sewage system applied in the buildings of the Central Administration, Rue Saint Lazare, works with the greatest regularity. The system was adopted by the company after its engineers had studied it and ascertained its practical value over any system of filtering tanks or "all to the sewer" since the system has been established in the buildings of the company; all the bad odors and inconveniences inherent to other systems have disappeared. In fact, it gives entire satisfaction from a sanitary standpoint.

PARIS, 18th January, 1886.

(Signed) MARIUS TOUDOIRE,
Architect of the Company.

FROM THE WESTERN RAILWAY COMPANY.

This company, wishing to apply in their new building that system of sewerage which would offer the best advantages in a sanitary point of view, have tried Berlier's pneumatic system in the public water-closets in the yard (Cour de Rome). It has worked well and given full satisfaction, no bad odor emanating from the apparatus.

PARIS, 29th January, 1886.

(Signed) LE CORBEILLER,
Chief Engineer 1st Division.

FROM THE CHIEF ARCHITECT OF THE P. O. RAILWAY.

The Paris-Orleans Railway Company, after having examined different sewage systems, decided to apply in their building, situated in Rue de Londres, Berlier's pneumatic system. The system has worked well since it was applied, and with the greatest regularity. The unpleasant odors of the water-closets have entirely disappeared. The undersigned is of the opinion that Berlier's system offers great advantages for the salubrity of houses.

PARIS, 29th January, 1886.

(Signed) LOUIS RENAULT,
Chief Architect of the Co.

The effect of the immediate removal of excretal matters by Berlier's pneumatic system is well attested by the results at the Pépinière Barracks. Since the application of the system not a single case of typhoid fever has occurred at these barracks, while it has prevailed with alarming intensity in the other barracks of the city. As to the cleanliness of the system, the *Architecte* remarks: "The depot to which the material is sent would "not be out of place on the *Boulevard des Italiens.* We cannot "say more. The cleanliness is extreme; without the least odor."

EXTRACTS FROM THE FRENCH PRESS.

Thanks to the Berlier system, there will be no longer any necessity for cesspools or movable tanks in Paris. This system has worked well at the Pépinière Barracks for some time, and not one case of typhoid fever has been observed among the thousand soldiers who live there. Unfortunately, this exemption from disease does not exist in other barracks of the city where the scourge has made many victims.—*Journal La Ville de Paris.*

The consequences of this immediate removal of excreta are very appreciable at the Pépinière Barracks. This quarter, heretofore so greatly infected, is to-day without disease or odor.—*Journal d'Agriculture Pratique.*

The result is absolutely satisfactory, and Berlier's system may from to-day be considered as a practical success.—*Echo des Deux Mondes.*

These experiments strike us as being most conclusive, and we do not doubt but the members of the Technical Commission appointed by the Prefect of the Seine will recommend it. The Berlier system is now the only one solving the question completely; it is the only one that allows the removal of human excreta as they are produced and without any contact with the surrounding air.—*L'Evenement.*

The removal of excrement by a pneumatic process of which M. Berlier, the engineer, is the inventor, and which has been working for some months at the Pépinière Barracks, where it has given the most surprising results, strikes us as being by far the best.—*Le Gaulois.*

We find ourselves in the presence of a true revolution on the question of excrement removal.—*Gil Blas.*

The attention and interest attached to this urgent question by some influential members of the Paris town Council led us to hope that Berlier's system would soon be recognized as one of public utility. Paris, by the adoption of this system, could have been rendered healthy this year, but the Council would not act. All the consequences of this delay will weigh on those who should have made extraordinary efforts to avoid them.—*L'Intransigeant.*

In fact, wherever Berlier's system has been applied, every contact of excretal matter with the air is rendered impossible, and infection is rendered quite improbable.—*La Presse.*

All who are interested in the hygiene of the metropolis will wish to see this new system installed.—*Le Radical.*

We are happy to see an *ensemble* of improvement which will render very great service. No more bad odors, no more nuisance caused by the visit of nightmen, and all this is replaced by a small iron box working automatically and without anybody's assistance.—*Le Clairon.*

This experiment shows, in the most absolute manner, that the cesspool emptying of times to come is the pneumatic one.—*Le Petit Journal.*

This is, we believe, an important reform which will be appreciated by the whole community.—*La Liberte.*

The results are highly satisfactory.—*Le Figaro.*

EXTRACTS FROM THE ENGLISH PRESS.

The apparatus has now been in successful operation at the barracks of the Pépinière for some time, and though 1,000 soldiers are quartered here, not one case of typhoid fever has occurred among them. These are the only barracks in Paris which have escaped. On the other hand, at the Gros Caillon and at the Chateau d'Eau, the barracks have been the principal centres of disease. Dr. Rochard describes one epidemic which attacked 1,000 soldiers out of 4,000 in the space of two months, killing 25 per cent. of the sick.—London *Lancet,* January 17th, 1883.

One advantage of this plan (the pneumatic system) is that it is self-acting, thus making no demand on a knowledge of sanitation. It is a significant fact that the Pépinière, with its one thousand soldiers, was the only barrack which escaped the typhoïd epidemic.—London *Times,* March 15th, 1883.

Fortunately, the French have before them a rival project to the "tout a l'egout," which, while it offers the best security for the preservation of public health, greatly facilitates the utilization of sewage matter.—The *Labor Standard,* April 21st, 1883.

The suction is from the houses ; the ingress of sewer gas into private houses is rendered impossible, and the streets cease to be a ventilating medium for the diffusion of those specific germs of which Pasteur has furnished us examples. This, technical authorities say, would be the best solution of a very grave question. The *Lancet's* special sanitary commission has backed this opinion in a recent exhaustive study of the causes of typhoid fever in Paris.—*Pictorial World,* March 17th, 1883.

These favorable criticisms on the Berlier system are applicable to the principles of pneumatic sewage generally ; but it would seem that the operation of the Berlier system had not been sufficiently studied and discussed at the time the above criticisms were uttered, since practical experience and closer investigation have shown defects and mistakes of construction which render the working of the system on a large scale difficult.

As far back as 1882, M. Hudelo, Engineer Officer of the City of Paris, in the name of a Commission of the Society of Public Medicine of Paris, in speaking of Berlier's system, said : "There "are certain complications and expenses involved in the system, "such as removing the 'baskets' more or less frequently; the "quantity of water necessary to be used, &c., which may render "the operation of the system in certain cases impracticable."*

This view did not seem to attract attention until recently, but now it is very generally admitted that there are defects which require to be overcome before it can be considered an efficient system for the disposal of the sewage of large cities. In a report, made in 1886, to the Royal Society of Public Medicine of Belgium, by a Commission, consisting of Messrs. A. Devaux, Inspector of Hygiene for East Flanders; F. Putzeys, Professor of Hygiene in the University of Leige, and G. Royers, Engineer of the City of Antwerp, this fact is recognized, and the Commission says: "Berlier's system, though very ingenious, is not well de- "termined as regards its working capacity in the removal of "the excrementitious matters from large cities. Its positive "value has not yet been definitely determined."

The chief objections to the system—which, however, are technical, and may be readily overcome—consist in the fact:

1. That the pneumatic pipes receive only excretal sewage, no provision being made for household and industrial wastes, which to satisfy the requirements of proper sanitation should be provided for.

2. That the "Receiver" and "Evacuator" consists of two separate pieces, heavy and cumbersome, which could be advantageously united into one of much smaller dimensions and simpler construction.

3. That there is no trap connected with the *receiver* to prevent gases, should any form, from passing up the soil-pipe into the house.

4. That no provision is made for the proper dilution of solid matters—fæces, paper, &c.—which gravitate at once to the

* Revue d' Hygiene, 1882.

bottom of the receiver, and sometimes occasion obstruction in the horizontal outlet pipe.

5 That the axle of the mixing apparatus, which is turned by a crank from the outside, forms in passing through the sides of the *receiver* dangerous joints, through which gases may readily escape

6. That the pedestals on which the *receiver* and *evacuator* rest are of no practical use, and consequently an unnecessary expense.

7. That there is no necessity for an apparatus weighing six or eight hundred pounds to receive a few pints of matter under no greater pressure than that of the ordinary atmosphere.

8. That the dimension of the floater being in proportion to the rubber ball valve attached to its lower extremity for the purpose of closing the aperture between the *evacuator* and the transport pipe, this dimension must necesssarily increase with the quantity of sewage sent down the fall pipe, as well as with the diameters of the evacuating pipes connected with the special canalization, so that for a house producing a larger quantity of sewage than that of an ordinary large family the number of apparatus must be increased or a special building provided to hold an apparatus of much greater dimension than usual, which would increase the cost of the system.

9. That the closing of the aperture between the *evacuator* and the pneumatic pipes being effected by a movable rubber ball valve, the least foreign substance interposed between the ball and circular margin of the opening will interfere with the working of the apparatus, allowing the outside atmosphere to pass into the pneumatic pipes, for a greater or less distance, occasioning serious disturbance in the working of the system as well as an increased expense; and, secondly, the shortest interruption in the circulation of matter passing through the

pneumatic pipes would cause the sewage coming from houses situated on elevated ground to be forced back through the apparatus in houses upon a lower level, and into the house itself; or again, the matter coming from houses on a high elevation may by gravity force the rubber ball valve in houses of a lower level, and thus pass back through the soil-pipe into the house. Lastly, there is never a complete emptying of the *evacuator*, and consequently never a complete communication between the evacuator and the pneumatic pipes, the sewage passing, as it were, into the latter, drop by drop, between the pulsations of the ball as it settles down into its resting place.

10. That the price of the Berlier apparatus ($80 each), added to the expense of fitting them up in the houses, must interfere with the successful installation of the system.

Taking into consideration the defects above set forth, it is manifest that the system of M. Berlier does not solve the problem of a complete pneumatic process for the removal of excrementitious matters from cities and centres of population, though the defects are all technical and may be readily surmounted.

CHAPTER XXIV.

The Domestic Sanitary System of A. Le Marquand.

THE most complete study yet made of the pneumatic process for sewage removal appears in the system just patented by M. Adrien Le Marquand, Civil Engineer of Paris, and a Director of the *Compagnie Generale de Salubrite* of that city, which company introduced the Berlier system and is still working it in the 8th and 9th districts of Paris.

Mr. Le Marquand has profited by his extensive experience, and in the new system which he has devised has avoided the technical mistakes found in other pneumatic systems.

This new and ingenious system for the sewering and draining of houses and towns or districts is based on the supposition that all sweepings, dust, kitchen waste and various other debris, more or less solid, will be collected and removed frequently by carts or other special appliances, and that rain water or surface drainage will be separately conveyed away by means of surface gutters or by its own system of sewers. Thus, there only remain to be dealt with by the pneumatic pipes, excreta, household slops, foul waters from factories and other foul or polluted liquids, and matters of more or less pasty nature capable of becoming measurably dissolved in water,—in short all such matters as are generally discharged into the waste or soil-pipes of houses. The main object of the system is to convey away these matters to such a distance from the town or district that they will no longer be injurious, and to do this automatically and continuously, before any fermentation is set up, in closed pipes or conduits, without contact with the air or with the surrounding earth.

We will first give a general description of the new system, and subsequently explain the essential parts by which it is carried into effect.

The superficial area of a large town is divided into several working districts, such as are indicated in the diagram (Fig. 1), the extent and boundaries of which are determined by the density of the population, the quantity of water which is each day at the disposition of the inhabitants, the number of houses and the character of the undulations of the land.

The matters which flow to the main soil or waste pipes, empty themselves, after having passed the last syphon or trap, into an automatic discharging apparatus of small size and great simplicity.

This apparatus, shown in Figs. 4 and 5, pages 128 and 129, is placed at the outlet of the premises and connected with a collecting conduit or pipe placed under the street or alley.

The mechanism with which it is provided operates automatically; as soon as the matters—a few gallons only—have attained a given level the contents are violently discharged into the collecting conduit, in which a constant barometrical depression is maintained.

A check valve placed between the apparatus and the conduit prevents, automatically, the return of any matters into the house under any circumstances.

In order to insure the regularity of the barometrical depression throughout the whole length of the collecting conduit, notwithstanding the simultaneous presence of sewage matters with this depression, that is to say, with a pressure of less than one atmosphere, and to avoid the frequent employment of pipes of large diameters, the collecting conduit of each district is divided into a series of mains of different sizes, of short lengths, communicating directly and separately with collecting tanks.

With the same object, the conduits are specially arranged where they have to be bent or dipped downward in order to pass some obstacle.

At a certain point of the district, by preference at the bottom of the slope, if there is one, two collecting tanks are placed, in which a regular barometrical depression is constantly maintained; these tanks, each in its turn, receive the liquids which come from the mains of the conduit, and send them on afterwards, automatically, with the aid of atmospheric pressure, to the central receiving and pumping works.

The central pumping works are provided with closed apparatus, absolutely air-tight, and are situated, where convenient, in the town itself, upon a site as near as possible to all the collecting tanks of the different districts; they are connected to these tanks by two conduits or pipes, one of which, the barometrical conduit (B) *Fig.* 1 into which no sewage matters ever enter—distributes amongst the collecting tanks and the different districts by direct communication the barometrical depression produced at the works by suitable pumps. The other conduit (C) serves, on the contrary, exclusively for the conveyance of the sewage matters.

Finally, the central pumping works, provided only with airtight apparatus, and with hermetically closed tanks, force the sewage matters by another conduit out of the town or district to as great a distance as may be desired, where they may be treated, utilized or purified, without nuisance or danger.

The gases, disinfected in hermetically closed vessels, can be employed to heat the engines of the works.

Having given a general description of the system, we will now proceed to describe in sufficient detail the means or apparatus by which it is carried into effect.

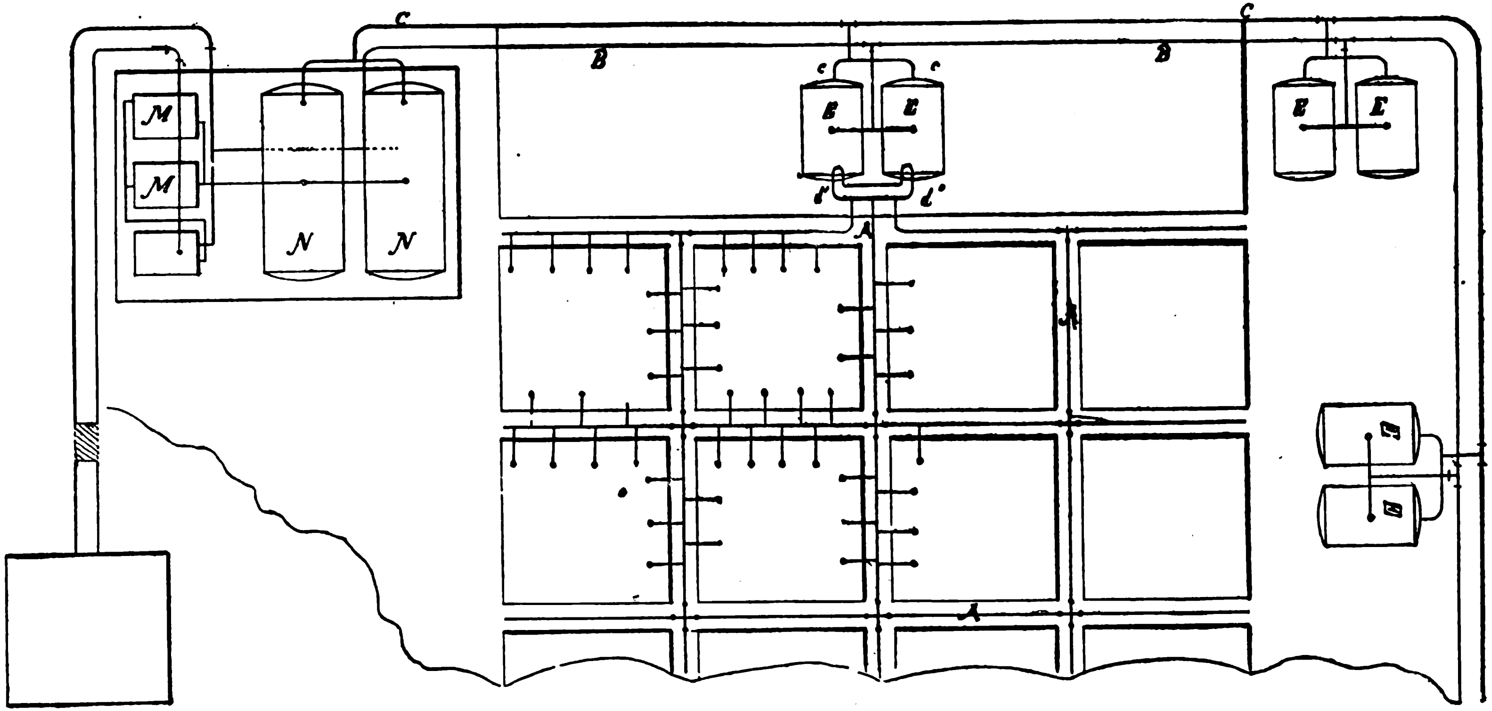
Working Districts (*Fig.* 1, 2 and 3).—It is difficult to indicate, in a general manner, the average extent of each district; in fact, when the houses are very close together, or are built in flats accommodating more than one family, the districts should cover less ground than when the houses are separated by gardens or the number of inhabitants is more limited.

Fig. 1, page 125, illustrates a general view of pipes connecting different sections of a city.

Fig. 2, page 126, plan of the city of Baltimore, showing at A A the two receiving and pumping works, which will receive the sewage of the entire city, and at C ten district tanks which will receive the sewage from four large mains.

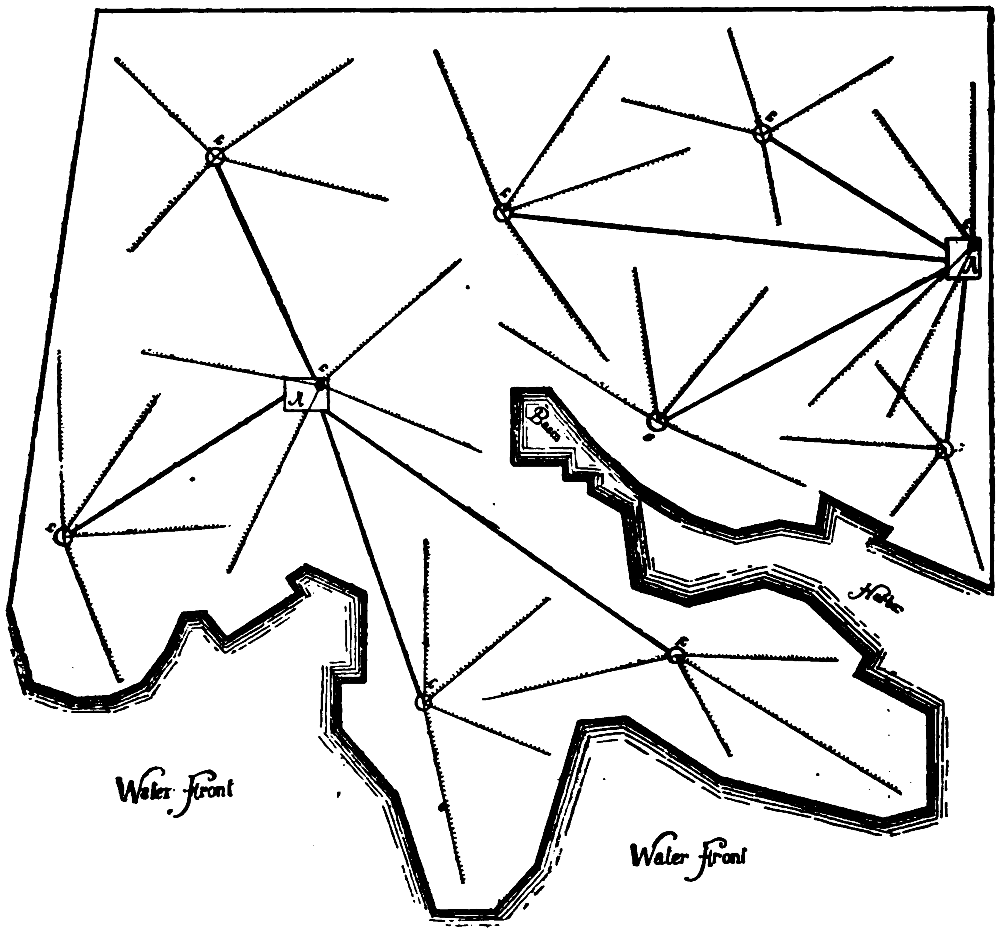
Fig. 3, page 127, design of a city of 100,000 inhabitants or less, divided into three districts, with collecting tanks grouped around receiving and pumping works. The central receiving

Fig. 1.



A.—Collecting pipes receiving sewage from houses.
E.—Collecting tanks of different districts.
N.—Central receiving works.
M.—Pumps.
□.—Central station, situated outside the city.

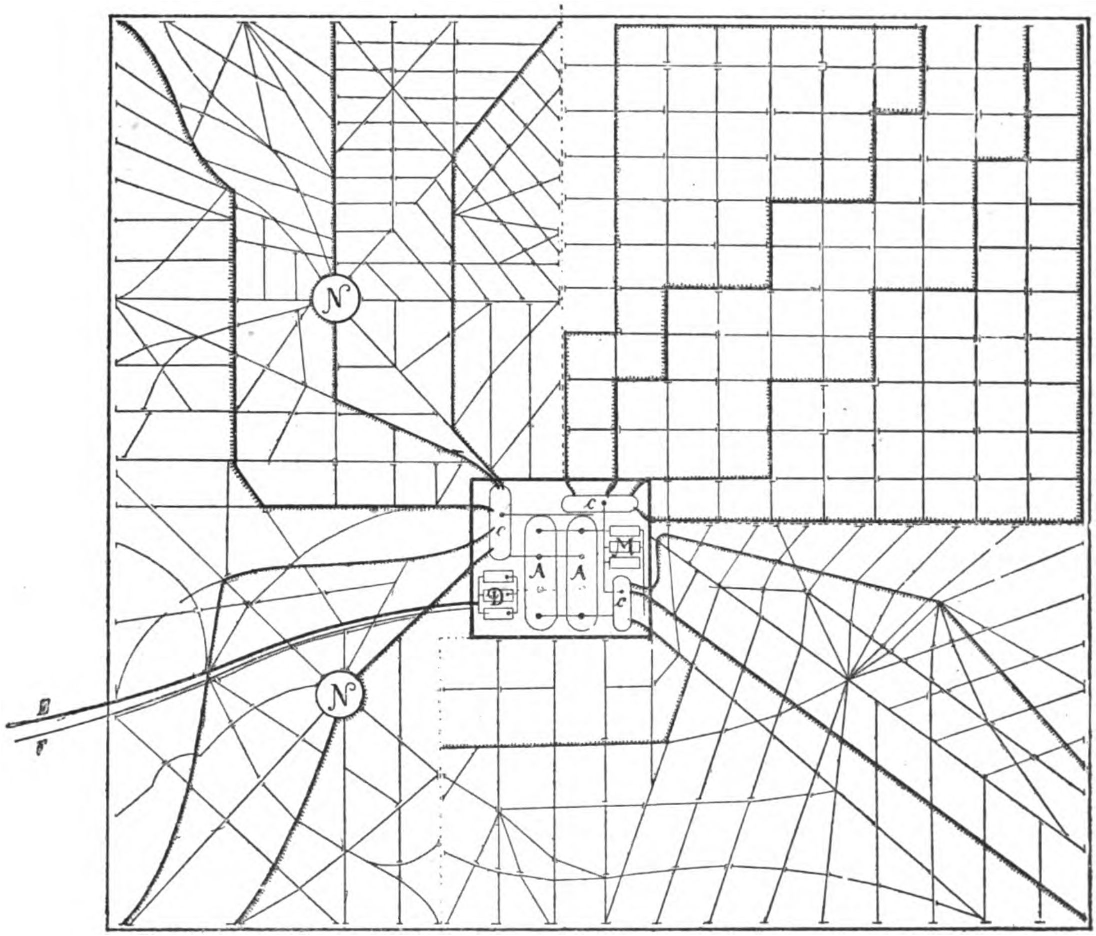
FIG. 2.—City of Baltimore.



station or works are shown large on plan; they will only occupy the area of an ordinary building.

The districts being composed of branches of the conduit or pipes of short lengths, connected with two automatic collecting tanks (E), their extent is limited only by the capacity and the normal delivery of these tanks, which fill and empty themselves automatically and alternately during the twenty-four hours, and should be able to send on to the central pumping works all the matter which they receive from the collecting conduit or pipe.

FIG. 3.

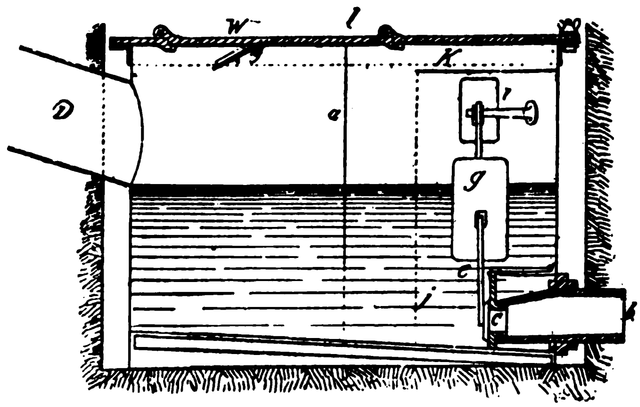


A.—Central receiving works.
C.—Collecting tanks.
D.—Forcing pump.
E.—Transport pipe.
F.—Pipe for the gases.
M.—Pneumatic pumps.
N.—Open square.

The districts are themselves divided into large, independent arteries or branches ; they are generally placed according to the inclination of the soil.

Automatic Discharging Apparatus (*Figs.* 4 and 5).—The automatic apparatus, which is situated between the main soil or waste-pipe (D) of the house and the collecting conduit or pipe placed under the street, is a light box of metal or other material, the shape and dimensions of which can be varied as required. Its mechanism is such that it can be made so as to be placed in a very limited space, generally under the ground, as near as possible to the surface, but at a sufficient depth to avoid the effects of frost. A simple hole in the yard or garden into which the soil-pipe passes is often sufficient to receive the apparatus.

Fig. 4.

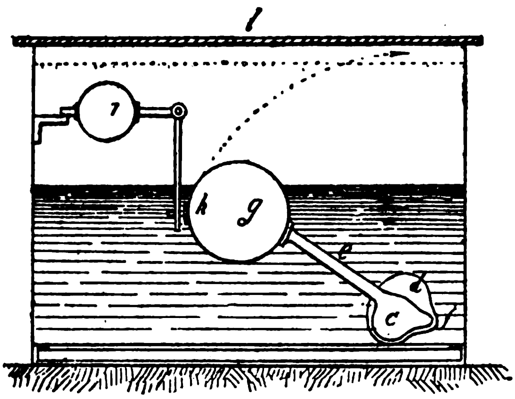


LONGITUDINAL SECTION.

It is divided into two closed compartments by a vertical partition (*a*), the lower part only of which is pierced with holes, or made of wire or lattice-work of any suitable metal. On one side of this partition, in the upper part of the apparatus, is the soil-pipe (D) from the house; on the other side is a pipe (*b*) which passes through the body of the apparatus to allow of its junction with the pipe of the collecting conduit situated further on under the street.

In the pipe (*b*) a vertical sluice or valve (*c*) of thick glass or other material is fitted in the interior of the apparatus; its seat is formed with an aperture corresponding to the diameter of the soil-pipe. This sluice or valve, composed of two polished plane surfaces, sliding one upon the other, alternately intercepts and opens communication with the collecting conduit. The face of the seat (*d*) of the valve is so arranged that the latter cannot leave it, whether open or closed.

Fig. 5.



TRANSVERSE SECTION.

To the arm of the lever (*e*) of this valve, mounted on the pin or axis (*f*), is fitted a metal float (*g*) of suitable form provided with releasing device (*h*) moved by another float (*i*) of smaller dimensions and placed above. The mechanism is enclosed in a metal casing (*j*) formed with holes and having a metal cover on top (*k*) provided with a latch, a padlock, or any suitable fastening. The two compartments of the apparatus are also each covered with a plate (*l*), which can be easily opened to permit of cleaning either compartment; this cleaning will only be necessary at very long intervals.

The cover of the compartment into which the pipe (D) discharges is provided with a valve (W) capable of opening inwards only to facilitate the action of the atmospheric pressure within the apparatus when the valve (*c*) is opened, so as not to exhaust the syphon or trap of the house pipes.

The apparatus, the partitions, the valve and its seat may be made of any suitable metal or material. All the metal parts may be galvanized or coated with tar to insure preservation.

The working of the apparatus is as follows: The apparatus receives the slops, fæcal and other fermentable matters from the soil or waste-pipe of the house. The matters that are more or less dissolved in water pass through the first partition (*a*), all foreign bodies and paper not yet destroyed, or insufficiently dissolved, and which the syphon or trap of the soil-pipe has allowed to pass, being retained or quickly dissolved in the bottom of the apparatus without obstructing the vertical partition.

The sirupy or pasty liquids pass through the casing of the mechanism, and their level rising in the apparatus covers the first float (*g*). As soon as it is immersed in these matters the float tends to rise, but is held by the releasing device (*h*), which only acts when the level of the liquid rises to the small float (*i*). At this moment the first float (*g*), being completely immersed, rises sharply to the final point of its travel in the apparatus, completely opening the valve (*c*) and the communication with the collecting conduit or pipe.

The atmospheric pressure then acts through the valve (W) upon the surface of the matters and drives them with force, first through the partition and afterwards through the open pipe into this conduit; the level immediately falls, compelling the small float (*i*), and the releasing device (*h*) with which it is provided, to resume their normal position. Whilst the level, in falling, allows the float (*g*) to descend, the valve (*c*), still immersed in the liquid, automatically closes, and the releasing device (*h*) upon which it then acts by its own weight is set ready for the next action. Thus the mechanism acts according as the height of the level of the liquid increases or diminishes.

The valve (*c*) during its movement rubs continually against its seat (*d*), and the to and fro movement which is imparted to it by the action of the float always keeps the mechanism in a perfect state of cleanliness.

It will be understood that when this valve is shut the pressure of the liquid upon its surface and the atmospheric pressure which acts upon it by reason of the barometrical depression maintained in the collecting conduit or pipe will keep it tight upon its seat, and that the polished surfaces of glass, for example, will not oxidize or deteriorate although immersed in liquid, and, that placed thus one against the other, they insure a complete and tight closing of the apparatus.

The Collecting Conduit or Pipe A (Fig. 1) is placed in existing sewers, drains or trenches under the street or alley as near as possible to the houses from which, by means of the automatic discharge apparatus, they receive the matters and liquids.

The pipes, which may be of wrought or cast iron, or other suitable material, need be capable of supporting externally a pressure only a little higher than that of the atmosphere, but the joints must be strictly tight. The conduit will consist of a number of pipes as long as it is possible to procure them. Its diameter will vary according to the number of houses it has to clear and the quantity of matter to collect

The numerous arteries or branches of the collecting conduit of a district should proceed in the shortest way towards the two collecting tanks of this district, after having received the matters from the adjacent smaller pipes, but as far as possible without communicating with each other on the way.

Pipes of different diameter can thus be employed in the mains of a district as well as in the various branches of the same main according as the quantity of material they have to collect in their course is more or less great.

These arrangements will insure throughout the collecting conduit an almost equal distribution of the barometrical depression which should be kept up in the tanks of the district, but as the speed of the gases in the pipes is very much greater than that of the liquids, and in order to facilitate the passage of the one over the other so as to obtain a very regular working of the system, it will be necessary to conform as much as possible to the following rules:

1st. When it is desired to effect the junction of a pipe conveying simultaneously the barometrical depression and the sewage matters with another pipe intended for the same purposes, the junction of the one which will deliver its matters to the other will be made upon the upper part of the other by means of a special piece of variable form, with single or double branches and of increased diameter at the point of junction.

2d. Whilst placing ordinarily the collecting conduit in the direction of the slope or incline of the district, it will be arranged at different parts in lengths of variable but slight inclination, discharging one into another.

With the arrangement indicated, while thus facilitating the equal distribution of the liquids and of the gases in the conduit, the barometrical depression therein is also equalized as much as possible.

The advantage to be derived from rapid declines for carrying forward the matters is no doubt lost, but this apparent loss is more than compensated for by the acceleration in the speed of the matters produced by their being carried forward by the gases whose passage is thus favored and whose speed is much greater. Moreover, this arrangement which facilitates the continual and sharp jerks of the sewage by the gases produces constantly a friction against the sides of the pipes, thus insuring their cleanliness.

Central Receiving and Pumping Works.—The barometrical conduit and the sewage conduit put the automatic collecting tanks in direct connection with the central receiving and pump-works.

Each of these conduits is composed of pipes of suitable material capable of resisting externally a pressure a little more than that of the atmosphere; their diameters are calculated according to the cube of the sewage matters and gases to be carried off from the district at the time of day when the delivery will be the greatest.

The central receiving works should be placed as near as possible to all the collecting tanks of the different districts of the town, and be joined to these tanks by the shortest road.

The reservoirs being put alternately in communication with the barometrical conduit B, transmit the desired depression to the collecting tanks, and throughout the whole of the conduit they will produce in the general receivers the necessary depression, so that the atmospheric pressure acting upon the full collecting tanks of the district will automatically force forward their contents.

It is claimed that the above is a system of sewerage or drainage for houses and towns or districts, composed of apparatus which receive the sewage matters from the waste or soil-pipes of the houses and discharge them automatically into collecting conduits; of a series of collecting conduits, arranged in arteries and branches throughout the town or district; of a pair of collecting tanks arranged at a suitable point of the town or district, the two tanks of each pair receiving and discharging the sewage matters alternately; of a pipe through which the sewage matters are conveyed from the collecting tanks to pumping works; of another pipe communicating between the upper part of the collecting tanks and the pumping works; and of pumps or pneumatic engines which maintain a constant barometric depression in the last-named pipe and throughout the system, and also draw the sewage matters from the collecting tanks.

It is further claimed for the system that it will work with great ease and certainty, and that this system is more economical than any other; that it will secure the salubrity of towns by removing rapidly, and before fermentation takes place, the excrementitious matters and household slops to a central station at any desired distance outside the town, where it may be used for the purposes of irrigation, or be converted into a valuable fertilizer without contaminating either air, soil or water.

CHAPTER XXV.

General Conclusions.

1. That the proper disposal of sewage involves the beneficial appropriation of refuse matters, so as to make them actually productive, avoiding interference with those domestic uses of inland waters for which they are properly adapted.

2. That sewage matters should be made available for agricultural purposes, and the results in this respect are limitable only by considerations of expense as weighed against the value of the result.

3. That the great importance of avoiding all sources of unhealthy and offensive effluvia, and of preserving the foundations of buildings and the sub-strata of towns and cities in a dry and clean condition, creates an absolute necessity for relinquishing cesspools and all receptacles for sewage connected with any building or other place, except such as are thoroughly water-tight and for the most part air-tight.

4. That all unhealthy putrescible matters should be removed at short intervals from within the limits of centres of population, either by means of air-tight pipes, or in vessels or tanks hermetically closed.

5. That privy-pits, unless they are perfectly water-tight, will infect, (*a*) the surrounding soil by transudation of their liquid contents; (*b*) the air by exhalations or gaseous emana-

tions through a polluted soil; (*c*) the sources of domestic water supply by percolation through intervening strata of earth.

6. That the use of water from dug wells should be prohibited for drinking and culinary purposes in every instance where privy-pits not absolutely water-tight exist in proximity to or within 1,000 feet of such wells.

7. That there exists between the air of water-carriage sewers and the external atmosphere a constant interchange, and as is the air of the sewer, so will be the air of the street.

8. That without considerable fall or grade, flushing is utterly inefficient for cleansing sewers, except where the matter is carried by pneumatic pressure or aspiration, even in the case of small sewers with large quantities of water.

9. That the impermeability of brick sewers can never be absolute, and, therefore, should they convey excrementitious matters, the surrounding soil and the water of neighboring wells will be at all times liable to dangerous contamination.

10. That excrementitious matters ought to be rigidly excluded from all storm-water sewers.

11. That the epuration of sewage water by the soil alone is not efficient in a sanitary point of view, as has been demonstrated by both experience and chemical analysis.

12. That no system of sewage can be approved, which permits the pollution of either air, water or soil; and that, in order to fulfill the requirements of proper sanitation, all excrementitious matters and kitchen slops should be conveyed from towns by pipes absolutely air-tight, or in hermetically-closed vessels to a point sufficiently distant, where they may be manufactured into a dry manure powder without offense.

CHAPTER XXVI.

WATER SUPPLIES.

THE QUESTION OF POTABLE WATER.

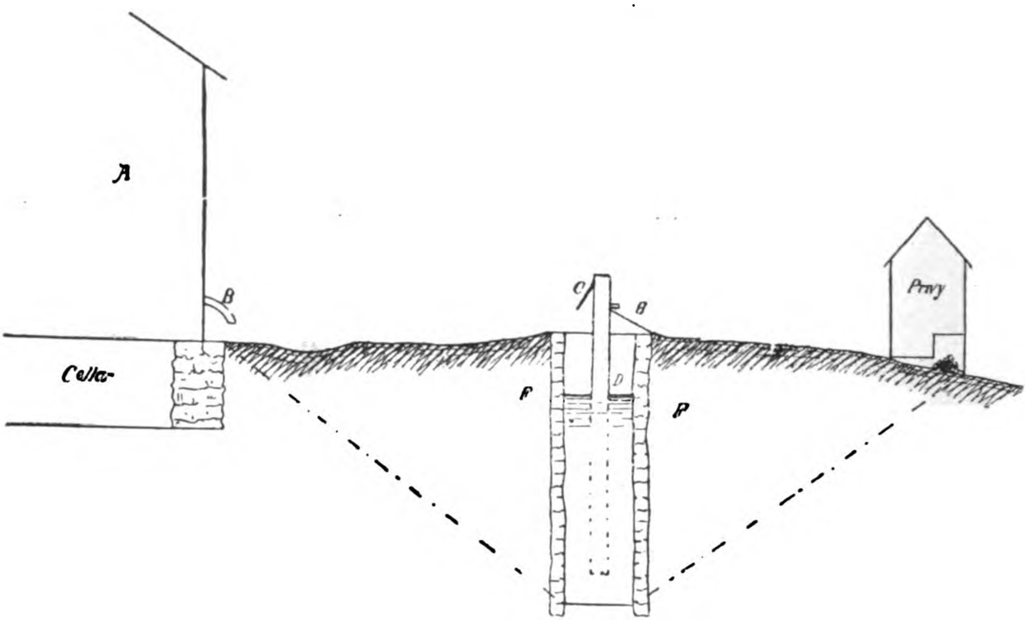
THE question of good drinking water is one of the first and most important to all communities; for water, next to atmospheric air, is the first necessity of living beings. It is for this reason that aggregations of population are generally found near rivers or rivulets, which serve a double purpose. They supply the populations grouped upon them with water, and are utilized to carry away the filth; but when the populations increase the latter condition can no longer be fulfilled without detriment.

It is a well recognized fact that the germs of infectious diseases are disseminated through the medium of water, and especially is this the case with reference to the germs of typhoid fever and cholera. These diseases have been known to pass from one community to another with a rapidity proportionate to the flow of the current of the river or stream on which the towns are located. In a report made to the Academy of Medicine of Paris by M. Marey, in October, 1884, after the outbreak of cholera in France, a number of cases are cited to illustrate the rapidity and certainty with which the disease is communicated from village to village by water courses. But it is not only the small towns which are exposed to the reception of disease in this manner; large cities are also subjected to the same prejudicial influence. In this manner cholera was carried to Genoa, Italy, during the epidemic of 1884. A week before the malady made its appearance in that city it prevailed at Bussola, a village situated on a small river, the Scrivia, where the women were in the habit of washing clothing. The supply of water to one of the aqueducts of Genoa is drawn from this river by means of a canal, and it was observed that in the beginning of the epidemic the disease prevailed only in that quarter of the city supplied with water from this particular aqueduct. The supply from this source was shut off, and an immediate amelioration of the disease ensued.

We know that in a great number of towns, wells of drinking water have been contaminated by the contents of privy pits soaking into the surrounding soil, and finally passing into the well by some direct channel, or by percolation with pluvial waters. More than a hundred epidemics of cholera and typhoid fever have been traced to this one cause. The extent of percolation will of course vary with the character of the soil; but instances are recorded where it has reached nearly one thousand feet. The report of Mr. Childs, Health Officer of Oxfordshire, England, contains a striking instance of the fouling of wells from a source above their level, which is reproduced here as forcibly illustrating the danger in question:

"In consequence of the escape of the contents of a barrel of "petroleum or benzoline which had been buried in an orchard, "a circuit of wells sixty feet below and 250 or 300 yards distant "became so affected that the occupiers of fifteen houses, con-"taining eighty-two inhabitants, were for ten days unable "to use the water for drinking or cooking. The cattle of one "of the proprietors, moreover, refused to drink at the spring "where they were accustomed to drink. Had this soakage been "sewage instead of petroleum, who can doubt that the result "might have been wholesale water-poisoning and an outbreak "of typhoid fever."

"Every well," says Dr. Frederick Winsor, "is the *drain* for "the moisture of a circumjacent region, which, at its minimum, "corresponds to an inverted cone, with its apex at the bottom "of the well, and with its base on the surface of the ground at "least as broad as the well is deep."* This is shown by the diagram.



A.—Kitchen.
B.—Sink spout.
C.—Pump 30 feet from house.
D.—Well 20 feet deep.
F.—Cone of soil draining into well.

Many examples of the transmission of diseases in this way are familiar to sanitarians, one of the most striking having occurred a few years ago at Chaterham, where a severe outbreak of typhoid fever was unmistakably traced to the water supply brought by mains from one of the great wells, over five hundred feet deep, belonging to the Chaterham Water-works Company, which had been accidentally polluted by the discharges from a single workman suffering with a mild attack of the malady.

Another remarkably clear example of the relation of drinking water to typhoid fever occurred in 1885, at Plymouth, a small city in Luzerne county, Pa.

* Seventh Report State Board of Health, Mass., p. 190, 1876.

I quote from the comprehensive report of the committee sent by the Mayor of Philadelphia to investigate the subject, as follows:

"The mountain stream is a small one, running down over a rocky bed, and on a declivity not eighty feet from its bed a dwelling is situated, wherein, during January, February and March, was located a case of typhoid fever that is only now convalescent, the worst period of the case being about the 30th of March. The attending nurse was in the habit, during each night, of carrying the excreta from the patient and depositing it on the ground towards the stream. The ground, during all this time, was frozen and covered with snow, until the thaw and rain already alluded to occurred. The poisonous character of the dejecta is not destroyed by freezing, but is only kept in a state of hibernation. A great part of the three months' accumulation of dejecta was suddenly swept into the rapidly-running stream, and reached the lower reservoir as quickly as a man walking fast would have arrived there.

"In fifteen days from this time the epidemic began, fifty cases occurring daily between the 10th and 20th of April. Up to the present twelve hundred people have been sick, and one hundred have died, out of a population of eight thousand. For the first three weeks the few people in the town who used well-water exclusively escaped the disease. The period of incubation varies from ten to twenty days, or longer, and therefore no other conclusion can be arrived at than that the infective poison existed in the mountain stream water, and originated from the one case of fever in the house on the side of the stream."

Dr. Brouardel, the celebrated hygienist of Paris, who has paid great attention to the water question, in a report recently made on the epidemic of typhoid fever at Pierrefonds, has demonstrated that the bacilli of this disease will live during many months in the earth, and are carried by rains into wells a considerable distance from the place where the dejections are thrown or deposited. It is also known that the microbes of other maladies are conserved for many days and even months in the earth. M. Pasteur has shown this to be the case with the microbes of charbon and septicemia, and his experience has lately been confirmed by Professor Bollinger, of Germany. Dr. Charrin, of Paris, has conclusively shown that the microbe of infectious pus will preserve its vitality for a long period even in a cultivated soil.

It is a great error to suppose that infected matter is rendered innocuous by dilution with water. Dr. Mead Bolton, following up the experiments of Koch and Flugge, has shown (*Nouvelle Revue d'Hygiene*) that the most dangerous microbes will not only live but multiply in the purest water when once introduced. The microbes of charbon, he says, will disappear in six days, but their spores, that is to say their eggs, will be preserved for twelve months. The microbes of typhoid fever have been observed to live in pure water for thirty days, and three months in water containing one grain of organic matter per quart of water, and their spores very much longer. As to the bacilli of cholera, dirty water is a marvelous medium for their propagation and growth; and even in ordinary water it has been ascertained that thev will live at least seven months.

Valffhugle and Riedel have demonstrated that the bacilli of cholera will, in a measure, destroy other bacilli which may be in the water with them, as certain fish destroy others; hence it is that the advent of one epidemic will sometimes terminate the existence of another, or, as Shakspeare expresses it, "one fire puts out another's burning."

Seeing then that the fæcal discharges of persons suffering from certain diseases are full of the microbes of those diseases, it is easy to comprehend how the percolation of such material into any source of drinking water may be fraught with disastrous consequences. It is indispensable to the health of communities, therefore, that the utmost care be taken to preserve the purity of water supplies, and to guard them with increasing care against every source of contamination.

The water of shallow or dug wells is always to be suspected, especially as the water in such wells is generally badly ærated, and is likely to contain extraneous and unhealthy matters. River water, which is excellent, if it has not been subjected to contaminating influences, depends for its purity, so far as suspended matter, such as muddy particles, is concerned, upon the nature of the surrounding soil and the velocity of the stream, but impurities of this kind are easily separated by means of filtration.

The sources of contamination in the neighborhood of towns are so numerous, and in reality so dangerous, that the supply of water from this source is often out of the question. When made available, the utmost care must be taken to draw the supply from a source above any town, so that sewage matter may not be present. Mr. Bailey Denton, the well-known agricultural engineer, advocates the storing up of the drainage water of agricultural land as a source of supply for small rural villages, he holding with many others that drainage water, instead of becoming contaminated by passing through cultivated land, possesses a positive superiority over other supplies. The following, from a paper by Mr. Denton, explains the mode he recommends:

"If we apply the system of storing drainage water for the "supply of villages in summer, we may test the question in its "monetary aspect by assuming the average population of rural "villages to be 400. If each inhabitant requires 10 gallons of "water per day (a quantity quite sufficient in places where the "water-closet system does not prevail and where the water "supply is used only for ordinary domestic purposes), it will "require a supply of 480,000 gallons for the summer. This "quantity is taken on the assumption that for 120 days, or four "months in the year, there will not be a supply from ordinary "sources. To secure this net quantity, a considerable allowance "must be made for waste by evaporation, and 50 per cent. on "the quantity required should be added to meet this loss. A "reservoir or basin to hold 720,000 gallons will therefore be "required, and this quantity of water must be stored.

"It requires very little calculation to show that if an "acre of land, during the period of discharge, will yield

"100,000 gallons, it requires less than 7¼ acres to yield "the required quantity for 400 persons, and 12 acres of "land where the soil is of the densest character. This "number of acres would have to be increased where the "rainfall is so far below the average that a minimum quantity "of 10 inches cannot be depended upon during the discharging "period. The reservoirs necessary to hold 720,000 gallons would "be rather more than two-fifths of an acre, if the depth were "taken at 7½ feet. This extent is too large for covering, at a cost "moderate enough for village economy, and therefore the prob- "ability is that open ponds will take the place of reservoirs, if "they could be made in some convenient place above the village, "and could be shaded from the sun and protected from the wind.*

"The expense of making the pond, using the earth to "embank it, and planting the embankment so as to exclude as "much as possible sun and wind, and thereby to reduce evapora- "tion and preserve the purity of the water, would be as follows:

Excavation and embanking, assuming that the earth thrown out formed a bank round the pond, on which trees and shrubs may be planted, 2,500 yards, at 12 cents	$300.00
Puddling bottom and slopes, dressing bank, and graveling bottom 6 inches deep on the puddling, and constructing overflow from reservoir	500.00
Planting and fencing	150.00
Value of land appropriated to the purpose (three-quarters of an acre)	100.00
Total cost of reservoir	$1,150.00
Iron pipes from reservoir, with stop-cock, well and brick work	750.00
Four stand pipes and traps	100.00
Total	$2,000.00

Assuming these figures to fairly represent the cost of supplying a village of four hundred inhabitants with water, and

* Considerable objection is taken to planting trees around reservoirs, because leaves fall into the water and cause impurity. But when the reservoir is annually emptied and cleansed at the end of the season of supply, this objection does not apply.

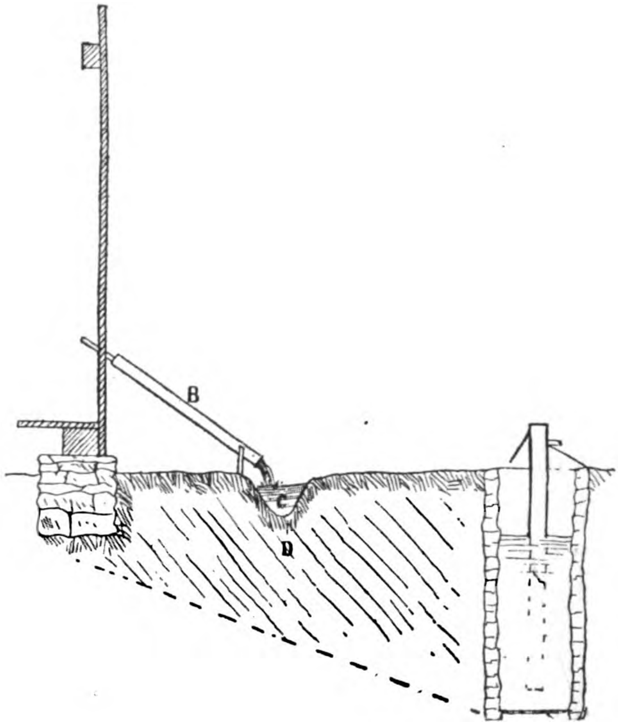
the number of houses or cottages in the village to be one hundred, it follows that the cost per person would be five dollars, and the cost per house, twenty dollars. If the cost were charged upon the houses, and the money were borrowed to do the work at five per cent., the annual charge would amount to one hundred dollars, or a charge upon each house of one dollar per annum.

The capability of thus supplying villages with water is not conjectural. Every day's experience only confirms the conclusion that there are few villages in which something of the sort might not be devised, and the saving to the community in improved health would far exceed in money value alone the cost of the work.

The water of natural springs and of deep artesian wells may be regarded as among the safest for domestic uses, and in Europe this fact is so well understood that water from such sources is generally preferred for the purposes of alimentation.

In rural districts, as in small towns, the "well" is the chief, and in many places the only source of supply. This often not only runs dry, but the supply is not of good quality, being frequently subject—especially in the case of houses near farm-yards and pig-pens—to contaminating influences, and most of the typhoid fever we hear of in the country is owing to this cause.

The following diagram illustrates how country wells may be contaminated :



B.—Wooden spout from stable and cow-house.
C.—Sink-hole or cesspool in farm-yard.
D.—Leaching from farm-yard into well.

If artesian wells are not practicable, then the formation of reservoirs or cisterns to receive the rain-water and replace the old wells is to be recommended. A French writer on the subject has a theory, which we are inclined to think nearly correct, that the "rainfall" of a country yields an ample supply for the wants of the inhabitants.

The location of the cistern is a matter of the first importance. Water possesses a remarkable power of absorbing and condensing many of the gases placed near or in contact with it. This power of absorption is such that it takes up many times its own volume. The proper "aeration" of water is an important point, and one which is not sufficiently attended to. While the presence of pure air, or "good aeration," tends to make water not only pleasant to the taste but healthful to the body, water subjected to an impure atmosphere, and thus being in a condition of "bad aeration," exercises a bad influence on the health of those partaking of it. Dr. Lyon Playfair states that he has not the least doubt that water exposed to an impure and noxious atmosphere is capable of absorbing noxious and impure matters, and in this way proving injurious to health; and Dr. Hassell has detected sulphureted hydrogen in the water in cisterns placed above water-closets and privies. The cistern, then, instead of being placed in a close, dark and confined situation, as it generally is, should either be out of doors, or in a part of the house well lighted and ventilated, so as to be easy of access at all times, and as far as possible from the water-closet, or any other source of foul air.

Of the form which may be given to the tank or cistern, that is altogether a matter of fancy. The circular is the strongest, although with the use of the Portland cement concrete, the rectangular may be adopted, as the framing required to form the mould for the concrete will be more easily made than that required for a circular tank. Lead as a material for lining cisterns should be rejected. Air and moisture coming in contact with lead will oxidize it more or less rapidly, and produce what is called a hydrated oxide when the lead has been in contact with pure water. Zinc has been much used for the lining of cisterns, but it is, in fact, more easily acted upon by water than lead. Galvanized iron has also been much used, but recent investigations show pretty conclusively that the zinc present in the galvanized covering of the iron is also quickly attacked by water, especially water in which air and saline substances are present. The question then is, what material is the best to be used? In country districts, where the cistern is generally outside the house, and plenty of space can be given it, stone or slate is the best material; and of the two slate is the best, as stone has been found to favor the growth of the green confervæ or weeds, and the softer the stone the more freely are the confervæ developed on its surface. But both slate and stone are bulky and heavy materials, and are, therefore, not suitable, or not so suitable for cisterns placed in the interior of houses. Taking all points into consideration, wrought iron cisterns are the best, and in Europe they are used almost entirely. They are light, cheap, and when well painted last a long time. In many instances the insides of these cisterns are coated with the tar composition used for the lining of the large cast iron pipes conveying town supplies of water.

The following is given as a rule for estimating the quantity of water obtainable from the roof surface of a house. If the rainfall averages 25 inches per year, this gives rather more than two cubical feet for every square foot of horizontal surface employed in catching it, or say 200 cubical feet of water to the square. Each foot contains 6½ gallons of water. A tank 15 feet by 19 feet by 7½ feet will hold 6,581 gallons, and about 5¼ squares of horizontal surface would catch enough rain water to fill it in the year at the above rate of rainfall. In estimating the area of roof, the level area only must be calculated, and not the surface area, which is often half as much again. Hence the simple method is to take the area of ground plan and double the number of feet contained in it, which will give the amount in cubical feet of water that on the average may be collected in each year.

It must be obvious, from what has been said, that the question of securing good water is one of the most important that can be considered by communities. It is not only necessary that the water supply should be pure, but it should be distributed in sufficient abundance for all purposes, and even to waste.

Indeed, it may be said, that the cleanliness and health of a town is usually in proportion to the quantity of water consumed. In this regard the present century has made great progress, but we are still behind the ancients in this important element of hygiene. The Romans in this respect have left a magnificent example in all the countries which they occupied. In no part of the world, and in no age has water been supplied in such prodigality as it was in the Eternal City during the period of the Empire. Twenty-two aqueducts formed by the streams of the neighboring mountains supplied the city, and of these enough exist at the present day to give to each of the 300,000 inhabitants an average of more than 800 gallons per day. It cannot be affirmed, however, that hygiene was the only incentive which led to such a prodigal supply; water was held in high esteem by this refined people for other purposes. It served to decorate and add to the pleasures of Roman houses, it supplied the fountains, the reservoirs, the immense basins for the "*naumachies*," or mock naval battles, and the public baths, which were erected for pleasure as well as health. But it cannot be denied that this abundant supply of water engendered habits of cleanliness and tastes which added greatly to the health of the people living in such a hot climate as middle Italy.

Since that epoch no city has been so abundantly supplied with water. In most English towns the water supply is calculated at about thirty gallons for each person daily. In America, wherever public water works exist, the consumption is much greater, the average Baltimore citizen using or wasting twice as much as his London cousin. Marseilles, the only city in France with a proper supply, when its projected works are completed, will be able to furnish an average of 300 gallons per day to each inhabitant, including industries. Paris, with a population of 2,500,000, has a daily supply of only 510,000 cubic metres (tons), or about 150 gallons per person per day, inclusive of water used for all purposes; but works are now being constructed which, it is said, will by 1889 increase this supply 140,000 cubic metres per day, giving a total supply of 650,000 cubic metres per day.

CHAPTER XXVII.

Chemical Properties of Water.

IN the Ninth Annual Report of the State Board of Health of Massachusetts, Prof. Wm. Ripley Nichols, in an elaborate article on "The Filtration of Portable Water," says:

"Comparatively few towns can congratulate themselves on "having in their possession, or even within their reach, a supply "of water which shall correspond in all points to the ideal "drinking water. Often the question must be decided between "an extravagant expenditure of money and a water which is "of an inferior quality although not actually unwholesome. "In theory, financial considerations stand behind sanitary considerations; yet in practice there is always a limit which "cannot be reasonably exceeded."

In practice it is often found necessary to decide upon a source of supply, which, although not actually unfit for use by reason of pollution, is nevertheless of inferior quality owing to the presence of suspended particles of vegetable or mineral matters, or to excessive hardness, or to coloring matter of vegetable origin in solution "In such cases," says "Prof. Nichols, "it is possible to improve the quality of "water, which, in its natural condition, is not well suited "for use. It may, however, be regarded as a principle "in sanitary science, that a water which is *polluted* by "admixture of substances known or generally suspected to be "injurious to such an extent as to require actual *purification*, "should be rejected at once as a source of domestic supply, but "a water too *hard* may be softened, and a water containing "matter in suspension may be clarified by some process of filtra-"tion."

Water derives its "hardness" from certain saline substances contained in it, of which the principal one met with is carbonate of lime or sulphate of lime, or chloride of sodium. These minerals are met with in nearly all waters, and do not of necessity render them impure, in the sense of being unhealthy, but when in excess they render the water very "hard."

The hardness of water is popularly recognized by the difficulty there is in making a soap lather with it, the salts in the water decomposing the soap and curdling it. With soft water—that is, water in which no salts of lime are present, only in minute proportions—the soap is not decomposed and no curdling is produced. When soap, therefore, is curdled, it is for washing purposes, whether of clothing or of person, just so much wasted. Hence the superior economy of soft water for washing purposes.

Much depends upon the purpose for which the water is to be used. If for drinking, a very hard water may be employed, and yet be considered soft, while if used for washing purposes, it will in reality be very hard. If the water is to be used for washing purposes, or for certain manufacturing purposes, for which soft water is best, inasmuch as the degree in which the water tends to curdle soap is the real measure of its value for these purposes, the best test by which to ascertain its value is unquestionably the soap test of Dr. Clark, which may be used where it is desirous to know the exact rate of hardness of a certain quantity of water.*

* This test consists in the use of a solution of soap, the strength of which is accurately ascertained. In proportion to the quantity of this solution required to form a lather with any quantity of water, so is its degree of hardness.

Soft water is not only more valuable for washing purposes, but it is also the best for cooking purposes. There can be no doubt of the fact that soft water certainly extracts much more quickly, and apparently more efficiently, than hard water, the nutritive properties of meat, in which boiling is useful, and in extracting the full natural value in infusions, such as tea and coffee. Nor should the prejudicial influence of hard water, as stated by the great majority of medical men, upon the health of the individuals regularly partaking of it, be overlooked. "From the very earliest periods in the history of medical "science," says an eminent authority, "the deleterious influence "upon the system induced by a continuous use of hard water "has been noticed. From the sick room it should be rigidly "excluded. Even with persons in good health, the use of it is "said to be almost immediately marked, if they have been "previously in the habit of using soft water. * * * It has "been remarked, both in England and America, that in such "districts as have a natural supply of soft water, there is "exhibited in the inhabitants a freshness of complexion not to "be found in any hard water district."

But, in considering the hardness of water, a distinction should be noted, and this is, that a water may be hard from the presence of salts which cannot be removed from it; this we would call a permanently or fixed hard water; while it may be hard from the presence of salts, which can be removed, and which is therefore a water hard only under these circumstances, so that the hardness may, by a certain process, be removed. Where the hardness of water arises from the presence of sulphate of lime (gypsum), it cannot thus be made soft; but if by the presence of carbonate of lime or lime-stone, it may be made soft, either by boiling or by the process of Dr. Clark, which has been very successful, and is thus described:

"To understand the nature of the process, it will be neces- "sary to advert, in a general way, to a few long-known chemical "properties of the familiar substance, carbonate of lime; for "carbonate of lime at once forms the bulk of the chemical "impurity that the process will separate from water, and is "the material whence the ingredient for effecting the separa- "tion will be obtained. In water carbonate of lime is almost "altogether insoluble, but it may be rendered soluble by either "of two processes of an opposite kind. When burned, as in a "kiln, carbonate of lime loses weight; and, if dry and pure, "only nine ounces will remain out of a pound of sixteen ounces. "These nine ounces will be soluble in water, but they will "require not less than forty gallons of water for entire solution. "Burnt carbonate of lime is called 'quick lime,' and water "holding quick lime in solution is 'lime water.' The solution "thus named is perfectly clear and colorless. The seven ounces "lost by a pound of carbonate of lime on being burned, consists "of carbonic acid gas—that gas which, being dissolved under "compression by water, forms what is called soda water. The "other mode of rendering carbonate of lime soluble in water is "nearly the reverse. In the former method, a pound of car- "bonate of lime becomes dissolved in water in consequence of "losing seven ounces of carbonic acid. To dissolve in the "second method, not only must the pound of carbonate of "lime not lose the seven ounces of carbonic acid that it con- "tains, but it must combine with seven additional ounces of "that acid. In such a state of combination carbonate of lime "exists in the natural waters of certain localities. Carbonate of "lime becomes what chemists call *bi-carbonate* of lime when it "is dissolved in water by carbonic acid. Any lime water may "be mixed with another, and any solution of bi-carbonate of "lime, without any change being produced. The clearness of "the mixed solutions would be undisturbed; not so, however, "if lime water be mixed with a solution of bi-carbonate of lime. "Very soon a haziness appears; this deepens into a whiteness, "and the mixture soon acquires the appearance of a well-mixed "whitewash. When the white matter ceases to be produced it "subsides, and in process of time leaves the water above per- "fectly clear. The subsided matter is nothing but carbonate "of lime."

Such is the basis of the process. Hard water contains lime in the form of bi-carbonate of lime. By the addition of lime-water, the lime is precipitated, and the water left above is clear, colorless and soft, not holding, in any sensible degree, either a solution of quick lime or bi-carbonate of lime. The process in domestic arrangements is easily carried out by having a quantity of ordinary lime water in a well-stoppered bottle, and using it to soften the water as required. Wherever the plan has been adopted it has been successful.

For drinking purposes hard waters are sometimes more agreeable to the palate than soft water; but this does not arise, as is generally supposed, from the saline particles which give hardness to it, but chiefly from the gases which it contains. Some waters, notoriously polluted with sewage and organic matter, are found to be the most agreeable possible to the palate; but this, from the fact that they contain a large percentage of fixed gas. Water well "ærated" is always agreeable to the palate, being known as "sharp;" but this quality may be found in perfectly soft water, as well as hard. Water not well "ærated" is not pleasant to drink—as, for example, water which has been boiled.

CHAPTER XXVIII.

ARTIFICIAL FILTRATION OF WATER.

THE artificial filtration of water on a large scale has become very general, where the supply is taken from streams or ponds. It has long been practiced by many European towns. In Germany, since 1858, there has been no town of any considerable size supplied with unfiltered river water, while the increase with reference to other sources of supply may be seen from the following data:

TOTAL NUMBER OF INHABITANTS IN EIGHTY TOWNS OF GERMANY, AUSTRIA AND SWITZERLAND.

SUPPLIED WITH.	1858.	1876.
Unfiltered river water	460,000	460,000
Filtered river water	1,060,000	1,697,000
Spring and ground water (by gravitation)	25,000	1,519,000
Spring and ground water (by pumping)	45,000	1,719,000

In America very few efforts have been made to secure better water supplies for our cities by improved methods of æration and filtration. At times, during the spring of the year, there are just causes of complaint regarding the condition of the water service in the city of Baltimore. A vast system, capable of supplying an average of 500 gallons per day per individual, has been constructed at great expense for the purpose of furnishing *pure water* to consumers; but it is in many respects disappointing. What we want is not only a plentiful supply, but a plentiful supply of *clean and pure water*, and if it is not so naturally, it should be made so by the best system of artificial filtration and æration possible.

For many years it has been observed that whenever the spring temperature reaches 68° or 70° Fahr., unpleasant changes take place in the water supply of Baltimore, owing, doubtless, to the great amount of vegetable matter growing and floating therein, and which, lodging in the angles and "dead ends" of the system of pipes, render the water for weeks offensive to the smell and unpalatable to the taste. This condition, so annoying to the consumers, could, no doubt, be obviated in a great measure by the adoption of artificial "æration," and a good system of filtration through sand and spongy iron, made use of at the pumping station or before the water enters the mains.

The low vegetable growths which occasion the trouble belong to that class of cryptogamous plants which the botanists call "*Algæ*." These plants grow in water, and although they are not killed by a considerable degree of cold, still they *thrive* only in warm weather. Observation would seem to point to a temperature of 70° Fahr., or thereabout, below which the trouble is not likely to begin. In some cases the abundant appearance of *algæ* has seemed to follow the apparent increase of sewage and other impurities discharged into the water supply; at any rate they are known to be highly nitrogenous and when in a state of decomposition or fermentative putrefaction, they are a "real cause of "a real trouble," such as the "fishy," "musty," "cucumber," "green corn," or other peculiar odor or taste which affects the water supply every spring.

There is no evidence that these minute vegetable organisms will impart positive unwholesomeness to water, from a supply which in other respects is of good quality; but they certainly give rise to serious annoyance, which should be gotten rid of at any cost. In such a condition the water is manifestly unsuited for domestic use.

Dr. Smart remarks that, "In England, where the relations "of the water supply to the public health are thoroughly "understood, a constant supervision is exercised over the "quality of city supplies, and any alteration from the normal "standard is followed by an inquiry into its bearing on the "wholesomeness of the water. This is as it should be. But in "our country public health work of this character is only "beginning to be appreciated. * * * The objective of all "sanitary inquiries is *prevention*, and this, in the case of dis-"eases propagated by the water supply, can only be effected by "a continued and general supervision which will throw out of "use the dangerous waters and suggest such precautions for "those that are of doubtful quality, before either of them have "forced themselves upon the public attention by unmistakable "evidences of their character."

Professor Nichols, who has given more attention to the question of water supplies than any other scientist in this country, says: "In localities where there is a public "water supply, it should be the duty of the Water Board "or Company to deliver the water to consumers in a con-"dition fit for domestic use, except in respect to tempera-"ture. If the source, which is, on the whole, the most "available for the water supply, is such that filtration "is absolutely necessary, the water should be filtered on "the large scale by the authority controlling the works. "Even taking into account the large amount of water used for "extinguishing fires, flushing sewers, watering streets, &c., it "would, no doubt, be cheaper in any given case to filter the "entire supply on the large scale than for each consumer to "filter with equal thoroughness his individual portion."

Even if the expense were equal, or if the filtration on the large scale were more expensive, there would still be objection on sanitary grounds to entrusting the matter to individuals, unless, indeed, the filters could be arranged in the line of the service-pipes, as gas or water metres are introduced, and be under the control of the Water Board.

For effecting filtration on the household scale numerous devices are employed; but it is well to remember that the success of any filter, in the accomplishment of its legitimate work, depends upon the frequency with which it is cleaned. No house filter should be used continuously for a longer period than two or three days without drawing off the contained water and allowing the air, which is much more destructive of organic matter than water, to pass freely through the filtering material for several hours. It would be well to have two filters and use them alternately every forty-eight hours. Vegetable charcoal, so frequently used in house filters, is particularly objectionable for the reason that, if not constantly changed, it attracts more readily than most other filtering materials minute forms of animal life. This objection, however, does not apply to animal charcoal, which possesses the power of bringing the oxygen dissolved in the water into chemical union with organic matter, and so destroying it, especially when the organic matter is in a state of decay and in an unwholesome condition.

Without entering into a detailed consideration of various filters which have been recommended and used, we may notice a very simple apparatus recommended by Dr. Parks: "Get a "common earthenware flower-pot; cover the hole with a bit of "zinc gauze or a bit of clean-washed flannel, which should be "changed from time to time; then get some rather small gravel, "wash it very well, and put it into the pot to the height of three "inches; then get some white sand, wash it very clean, and put "that on the gravel to the height of three inches; then take two "pounds of *animal* charcoal, wash that also by putting it into an "earthen vessel and pouring boiling water on it; then, when "the charcoal has subsided, pour off the water and put some "more on for three or four times. When the animal charcoal "has been thus well washed, put it on the sand and press it well

"down. Have four inches in thickness of the charcoal, if pos-
"sible. The filter is now ready. Pour water into the pot, and
"and let it run through the hole into a large glass bottle.

"After a time the charcoal will get clogged; take off a little "from the top and boil it two or three times, and then spread it "out and let it dry before the fire. It will then be as good as ever. "From time to time all the charcoal and the sand also may "want washing. The sand may be put over the charcoal, and "not between it and the gravel; but this plan sometimes leads "to the charcoal being carried, with the water, through the "gravel and out of the hole. The sand stops it. By filtering in "this way, and by boiling the water, many dangers are done "away with."

CHAPTER XXIX.

Methods of Analyzing Suspected Water.

PROF. R. C. KEDZIE, who has paid a great deal of attention to the analysis of potable waters, recommends, as simple tests of the purity of water, the following:

Color.—Fill a large bottle made of colorless glass with the water to be tested; look through the water at some black object; the water should appear perfectly colorless and free from suspended matter. A muddy or turbid appearance indicates the presence of soluble organic matter or of solid matter in suspension.

Odor.—Empty out some of the water, leaving the bottle half full; cork up the bottle and place it for a few hours in a warm place; shake up the water, remove the cork, and critically smell the air contained in the bottle. If it has any smell, and especially if the odor is in the least repulsive, the water should be rejected for domestic use. By heating the water to boiling, an odor is sometimes transevolved that otherwise would not appear.

Taste.—Water fresh from the well is usually tasteless, even though it may contain a large amount of putrescible organic matter. Water for domestic use should be perfectly tasteless, and remain so even after it has been warmed, since warming often develops a taste in water which is tasteless when cold. If the water, at any time, has a repulsive or even disagreeable taste, it should be rejected.

Heisch's Test for Sewage Contamination.—The delicacy of the sense of smell and of taste varies greatly in different individuals; one person may fail to detect the foul condition of a given water, which would be very evident to a person of a finer organization. But if the cause of a bad smell or taste exists in the water, the injurious effects on health will remain the same, whether recognized or not. Moreover, some waters of very dangerous quality will fail to give any indication by smell or taste. For these reasons especial importance is attached to Heisch's test for sewage contamination, or the presence of putrescible organic matter. The test is so simple that any one can use it Fill a clean pint bottle three-fourths full with the water to be tested, and dissolve in the water half a teaspoonful of the purest sugar—loaf or granulated sugar will answer; cork the bottle and place it in a warm place for two days. If in from twenty-four to forty-eight hours the water becomes cloudy or milky, it is unfit for domestic use. If it remains perfectly clear, it is probably safe to use.*

Wanklyn Test.—The "Ammonia" is determined by distilling a measured quantity of water with carbonate of soda, and

*Hunt's *Principles of Hygiene*, p. 50.

"the albuminoid ammonia" is determined by the method of Wanklyn and Chapman, which consists in subjecting water which has been freed from ammonia, to distillation in the presence of a strongly alkaline solution of permanganate of potash. Most nitrogenous substances, under such treatment, give off a portion of their nitrogen as ammonia. This amount is constant for any one substance, but different organic substances disengage different amounts of ammonia. The term "albuminoid ammonia" is used because albumen acts in this way, and the substances in ordinary water, which give off ammonia under these conditions, may be regarded in some sense as allied to ammonia.

Frankland Test.—In the Frankland process a given quantity of water is evaporated, and the residue is submitted to an organic analysis which converts the carbon into carbonic acid and liberates the nitrogen. The relative proportions of carbon and nitrogen indicate the character of the organic matter. Total solids should not exceed fifteen grains per gallon.

The Biological or Koch method is the application of tests which determine the minute organisms in water, since impurity multiplies such animal and vegetable life therein as is believed to be often the efficient cause of disease.

APPENDIX.

A NEW SYSTEM OF SEWAGE DISPOSAL.

Separating and Filtrating Process.

The Invention of Dr. C. W. Chancellor, of Baltimore, Md.

(*Patent applied for.*)

This new and useful invention, which is now for the first time brought to the attention of the public, is applicable both to aggregations of population and to isolated buildings. It consists of a thoroughly tight receiver (see diagrams), constructed of any suitable material and of any convenient form, which is placed in the cellar or any lower room, or as near the house as practicable. This receiver is divided transversely into two compartments—called respectively the "Receiving" and the "Overflow" compartments—by a vertical partition or diaphragm which extends from within a few inches of the top to the bottom of the receiver, and the whole is covered by a close-fitting, movable top or hinged door, for the purpose of cleaning the apparatus when necessary.

The bottom forms an inclined plane in the direction of the length of the box, or converging to its centre, where there is an opening in the bottom, to which is attached a thoroughly tight receptacle or "holder" for the solid matters, which can be removed at will. Through the top of the "receiving compartment," or opening into the side of it, the soil or fall-pipe passes to within a few inches of the inclined bottom, and terminates in an open flanged or funnel-shaped extremity.

The excretal matters or house refuse, brought down by the fall-pipe, drop upon the inclined bottom, and being heavier than water descend at once into the "holder," which is provided with an automatic register or index to indicate when it requires to be emptied. When full it is detached and hermetically closed for removal.

The "receiving compartment" is subdivided horizontally into two parts, about one-third its depth from the bottom, by a perforated grating or "strainer," through which the soil-pipe also passes, unless it should enter the compartment by a separate sub-compartment, or pass through the side below the strainer. The grating supports as filtering material: *First*, a loose bed of coke or sifted cinders, which acts mechanically by separating or retaining the solid particles of matter which tend to pass upward through the "strainer:" *Second*, a layer of wool, held loosely in place by a woven wire grating, The wool also acts mechanically in arresting such suspended particles of solid matter as may have escaped the "strainer" and the coke. It possesses the advantage of retaining its porosity for a great length of time, and does not easily become clogged, even when a highly impure fluid is passed through it.

The sewage water or other fluid passing upward through these media, which are so arranged as to be easily removed and cleansed, flows over the upper edge of the partition into the second or "overflow compartment," which is arranged as follows:

Upon the bottom of this compartment there is a bed of broken stone, or coarse gravel; upon this a bed of spongy iron, iron filings, or carbide of iron; and, lastly, a bed of animal charcoal or quartz sand, or both. The sand acts both chemically and mechanically upon water containing organic impurities, by forming nitrates and arresting them; the animal charcoal possesses the power of bringing the oxygen dissolved in the water into chemical union with the organic matter, and so destroys it, especially when the organic matter is in a state of decay and in an unwholesome condition; the iron turnings, or spongy iron, possesses the property of removing considerable quantities of organic matter from solutions containing it, and the broken stone aids in "ærating" the fluids passing over and through it.

At the bottom of this compartment there is an escape pipe through which the filtered liquid flows in a condition perfectly freed from contaminating matter, and may run into the street gutter or over the surface of the ground, or into the nearest water course, where the water is not used for dietetic purposes, with entire impunity.

Preliminary to using the apparatus, the "receiver" and the "holder" are both filled with clean water. The solid and liquid excreta are passed into the receiving compartment through the soil or fall pipe, which opens under the water near the floor of the inclined plane, upon which they fall, and being of greater specific gravity than ordinary water they are kept below and gravitate to the bottom of the "holder," displacing an equal volume of water, which passes upward through the filter of the first or receiving compartment, and then over the top of the diaphragm downward through the successive layers of filtering material in the second or filtering compartment; thus all solid matters gravitate into the "holder" below, and all liquids, whether from closet or kitchen, must pass through the various filtering media before escaping to the open air, the operation going on continuously, or whenever there is a flush in the fall pipes.

When the lower receptacle or "holder" is filled with solid matter the opening between it and the upper receptacle is closed, and the full vessel removed and replaced with an empty one. The connecting aperture being then opened the liquid in the upper receptacle descends into the lower, and in passing down through the wool and coke carries with it any particles of suspended matter which they may have engaged, and thus the apparatus is, as it were, automatically cleansed; or, if desirable, the wire baskets containing the filtering material can (one or all) be raised at any time and refilled with fresh material at a cost of two or three cents.

In order to cleanse the second filter it is only necessary to remove occasionally a thin stratum of the sand or animal charcoal at the top, which will contain all the impurities that may have escaped through the first filter. As the filtration here is downward and intermittent, the process of cleansing is also automatic, for as the water passes downward and leaves the filtering material (the exit aperture being always open) it is followed by successive currents of atmospheric air, which serve to oxidize and destroy any organic impurities engaged in the interstices of the filtering material; hence the filter is at all times clean and in a condition to receive and act upon new liquids. *

It is quite evident that this process of filtration has supplied us with the means of getting rid of all the suspended impurities in the sewage water which could prove offensive or detrimental, and it now remains only to provide a means of suppressing the volatile properties, such as ammonia, which might possibly rise to the surface and find their way into the atmosphere. This may be effected in two ways, and by very simple processes, either of which would be efficient:

1. To the top of the partition, which divides the two compartments of the apparatus, a porcelain or glass vessel is attached containing muriatic acid, so that its surface is in free communication with the vapors or gases, if any, issuing from below. The ammonia combines with the muriatic acid, losing entirely its volatility and forming crystals of muriate of ammonia.

2. A wicker frame or basket containing sulphate of lime (gypsum) is placed on the inner side of the apparatus above the surface of the water. Now, according to Liebig, carbonate of ammonia and sulphate of lime cannot be brought together at common temperatures without mutual decomposition. The ammonia enters into combination with the sulphuric acid, and the carbonic acid with the lime, forming compounds destitute of volatility, and consequently of smell. This principle is well-known to intelligent stable men, who strew the floors of their stables, from time to time, with common gypsum, which destroys all offensive smell, and none of the ammonia is lost, but it is retained in a condition serviceable for manure. †

This apparatus can be readily applied to the present water-closet system without any change whatever in the construction of the same, but admits of closet apparatus of a much more simple character than those now in use, for the lower end of the discharge or soil-pipe being at all times under the water, there can be no escape of gas up the pipe into the building, as is the case from the ordinary cesspools or sewers, and consequectly no necessity for extending the soil-pipe above the roof. It is true that certain soluble principles of the dejections may rise and mingle with the water in the pipe, but the amorphous and putrescible matters remain below, and should decomposition take place in the holder, which is not probable since its contents are always hermetically closed, the product of such decomposition, in the form of gas, would be absorbed by the water. According to Prof. Hoffman 1,000 gallons of water dissolve at the common temperature, 46 gallons of oxy-

*Atmospheric air is a much better cleanser of filtering material than water.

†"Chemistry in its Application to Agriculture and Physiology," by Justus Liebig. Edited by Drs. Playfair and Gregory, page 189.

gen, 25 gallons of nitrogen, 2,500 gallons of sulphureted hydrogen, 1,000 gallons of carbonic acid, 500,000 gallons of ammonia. The latter gas is that which usually escapes from decaying excretal matters.

The necessary dimensions of the "holder" can be easily determined when we remember that the quantity of solid excretal matter yielded per day by each individual of the population—taking all classes and all ages together—is less than three ounces. Thus a "holder" of 200 pounds capacity will contain the solid excreta of ten persons more than three months and a-half.

Advantages of the System.

First. It affords absolute protection against the dangers which ordinarily arise from the decomposition of excretal matters and the refuse waters of the house.

Second. The apparatus being both water-tight and air-tight, the surrounding soil and adjacent waters are protected against any contamination by foul matters; at the same time, the dejections being excluded from exposure to atmospheric air, there is no fear of malodorous or unheathy emanations,

Third. The soil-pipe being hermetically closed at its lower extremity, there is no circulation of air through it to carry the gases, should any exist, into the house, and consequently no necessity for trapping the soil-pipe or for extending it above the roof. The tendency of any gas which might be disengaged from excrementitious matters adherent to the inner side of the soil-pipe will be, with each flushing process from the closet bowl, downward, and being thus carried to the bottom of the reservoir, they are absorbed by the water contained therein.

Fourth. While this system provides a means of getting rid of excrementitious and other household refuse matters in a manner to satisfy the sanitary requirements of the question, it at the same time preserves them for ultimate disposal in a manner to satisfy the requirements from an agricultural point of view.

Fifth. In applying the system, the existing closet arrangements can remain as they are; and for kitchen slops, it is only required to join the sink of the kitchen and pantry with the fall pipe from the closet, or directly with the reservoir.

Sixth. The excretal and refuse household waters, by a process of mechanical and chemical filtration, are deprived of all noxious substances, whatever they may be, in a manner to render them practically pure, and they may then be discharged into the public highways or sewers, or water courses not used for dietetic purposes, without danger of creating any offence whatever.

Seventh. The system secures to communities, large or small, a safe, cheap and effective sewerage for both household and manufacturing wastes, discharging them in a manner in which they can neither pollute air, nor soil, nor public water courses.

Eighth. Its crowning characteristics are simplicity of construction and permanence of action, with the least original outlay at which these qualities can be obtained.

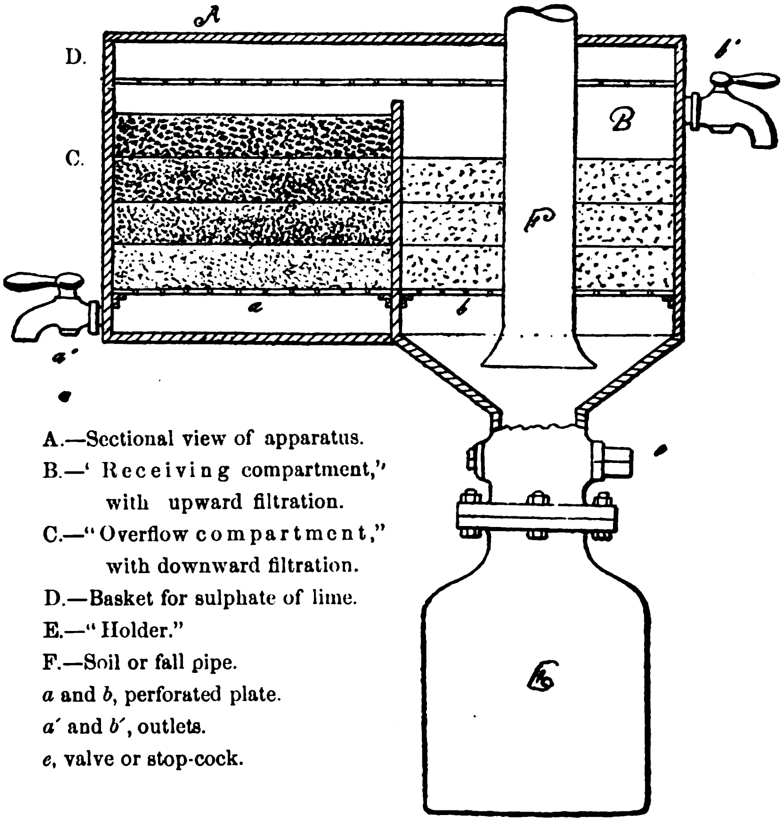
The Question of Cost.

It is evident that there is no reason why an apparatus or receptacle of the kind described, in which the sewage is collected, stored, and removed every three or four months, should be in any respect obnoxious to the senses or injurious to the health of human beings. Can the remaining question of cost be disposed of with equal satisfaction, considering that the application of the sewage to manuring purposes may be effected with due economy? We believe it can.

The total expense will embrace: 1. The construction of the apparatus. 2. The current expenses of collecting, transporting and chemically treating the material. These expenses will be less in the aggregate than the cost of constructing, cleaning and keeping in repair an ordinary privy-pit. But a reduced estimate of the value of sewage sludge, which has not undergone putrefactive fermentation and consequent loss of ammonia, such as takes place in excreta contained in an open cess-pit, or privy represents it at $1 per person, per year, so that against the total cost of the "Filtering and Separating Process," in a comparative estimate, is to be placed the value of the sewage sludge, which by this process loses none of its inorganic properties, and may be readily and easily converted into a valuable fertilizing agent.

In towns of more than 5,000 population works can be erected for treating the sludge by converting it into a commercial dry manure powder, the increased value of which as a fertilizing agent would much more than pay the interest on the cost of the works and operating expenses.

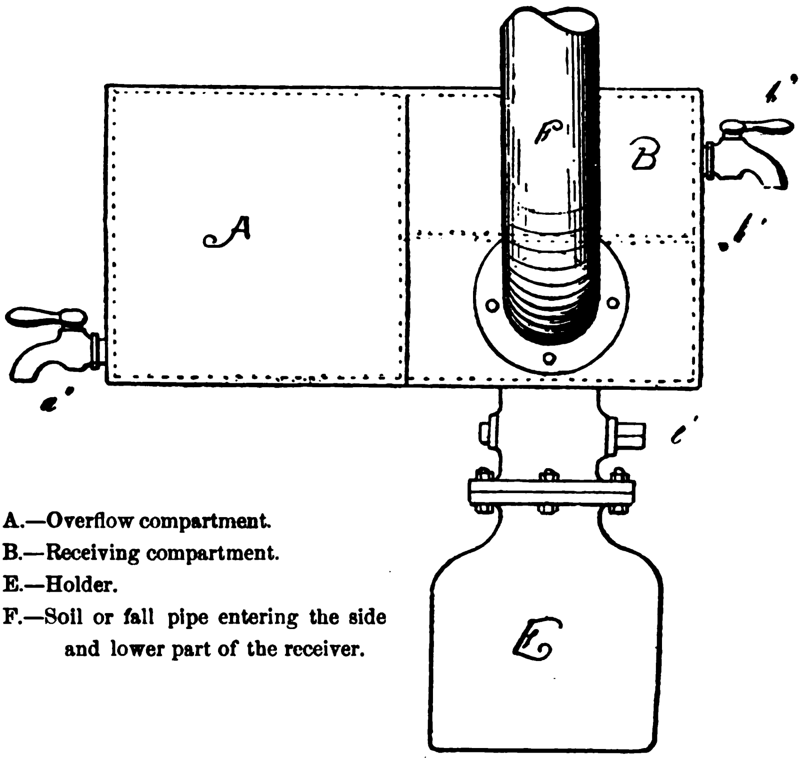
Fig. 1.



A.—Sectional view of apparatus.
B.—' Receiving compartment,'' with upward filtration.
C.—"Overflow compartment," with downward filtration.
D.—Basket for sulphate of lime.
E.—" Holder."
F.—Soil or fall pipe.
a and *b*, perforated plate.
a′ and *b′*, outlets.
e, valve or stop-cock.

Referring to the drawing, Fig. 1, (*A*) is a sectional view of the apparatus showing the layers of filtering material as they are arranged on the perforated plates (*a*, *b*); (*B*) designates the "receiving" and (*C*), the "overflow" compartments, arranged respectively, for upward and downward filtration; (*D*) represents the wicker frame or basket which contains the sulphate of lime or gypsum, and (*F*) the soil or fall pipe from closet, terminating below the perforated plate (*b*), near the opening into the holder (*E*), which receives the solid matter. It will be observed that the water stands at all times in the soil or fall pipe (*F*) as high as the top of the partition which divides the receiving compartment (*B*) and the overflow compartment (*C*), so that the end of the pipe is practically sealed, and, consequently, there is no upward draught or escape of gases through it into the closet above.

Fig. 2.



A.—Overflow compartment.
B.—Receiving compartment.
E.—Holder.
F.—Soil or fall pipe entering the side and lower part of the receiver.

Fig. 2 represents a side view of the apparatus, showing the soil or fall pipe on the outside of the receiving compartment (*B*), and leading into it below the filtering material.

Fig. 3.

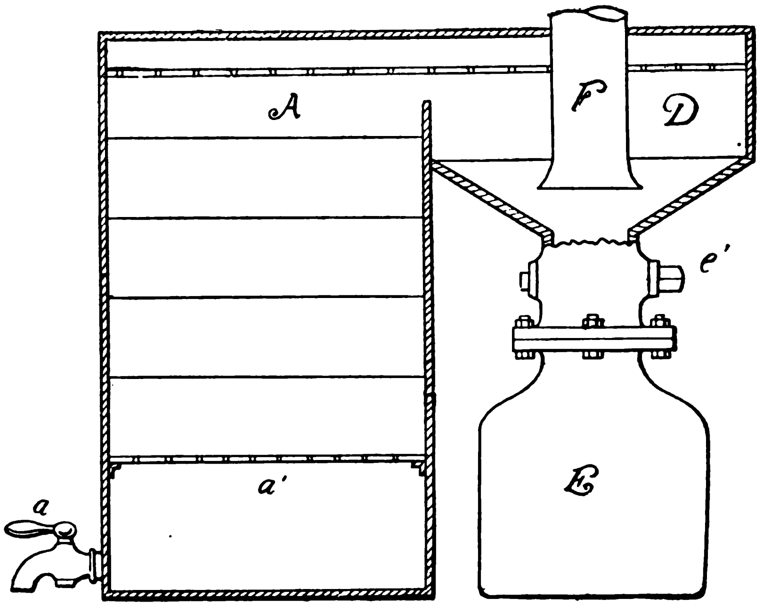
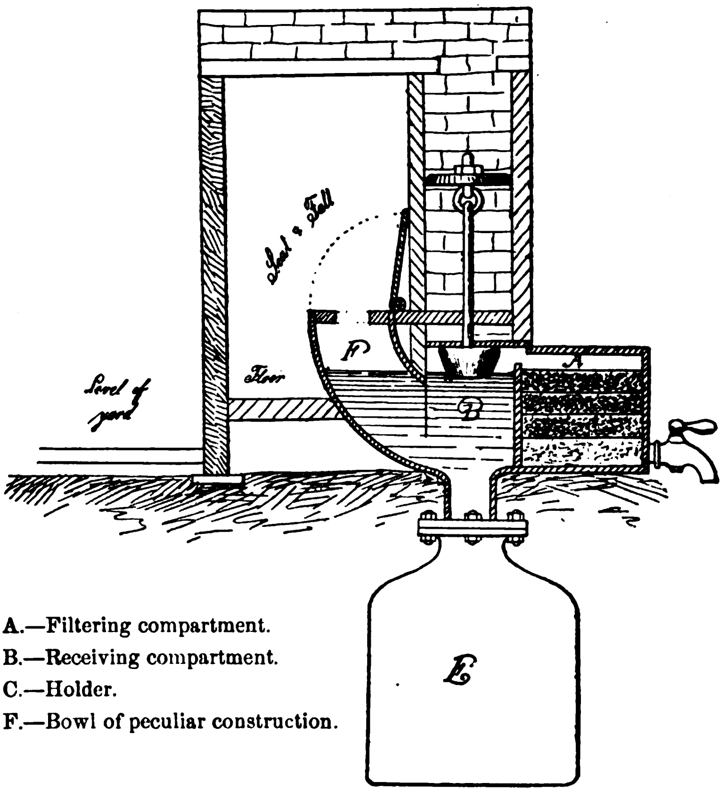


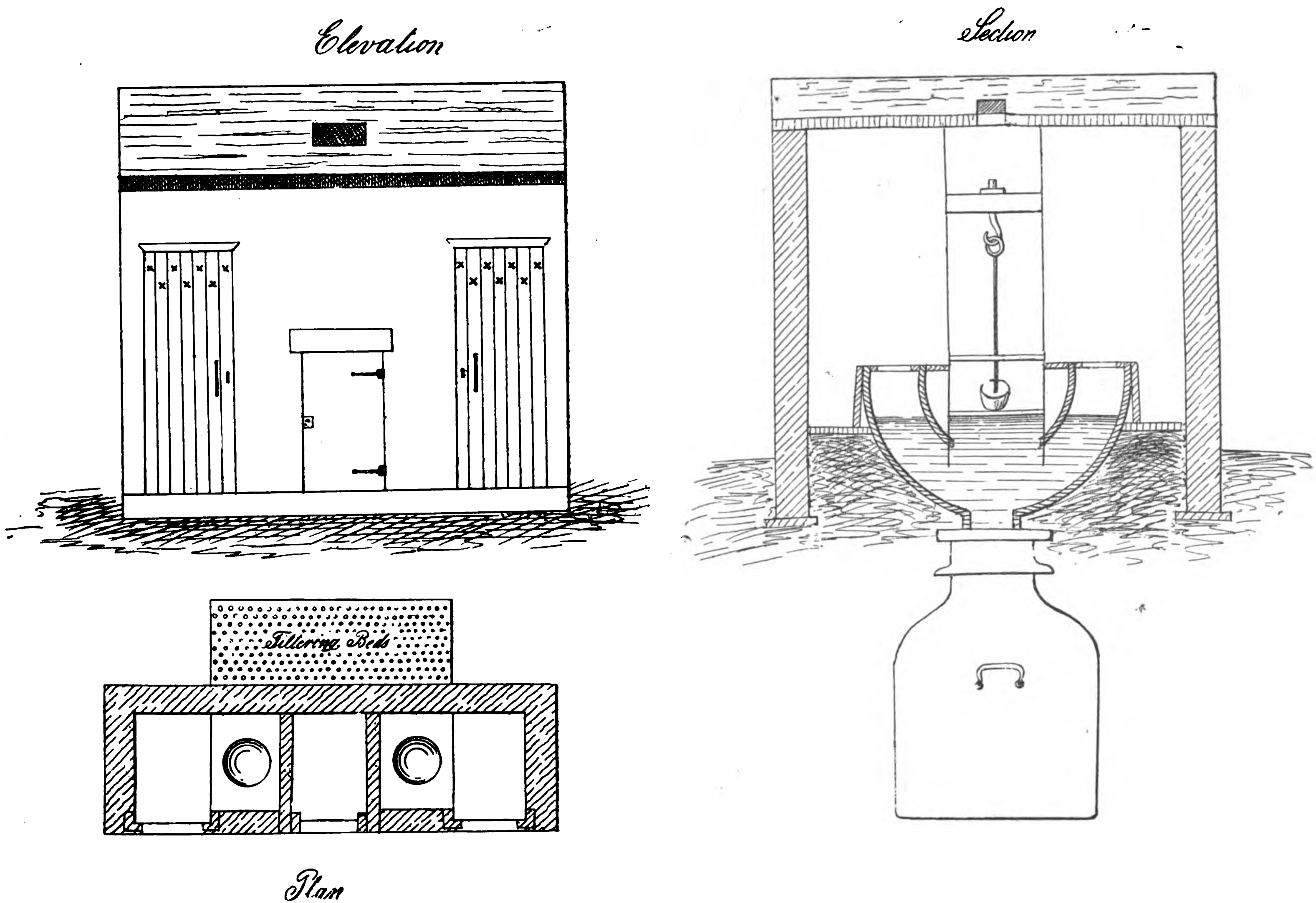
Fig. 3 illustrates a modified form of the apparatus of compact construction, which is more economical than that shown in Fig. 1 and occupies much less space. In this arrangement, it will be observed, there is only one filtering compartment (*A*), which, however, is quite sufficient for all practical purposes. The compartment (*D*) is filled with a layer of wool which is held in place by a wire-gauze cover, which arrests the floating particles of organic matter.

Fig. 4.



A.—Filtering compartment.
B.—Receiving compartment.
C.—Holder.
F.—Bowl of peculiar construction.

Fig. 4 shows an arrangement for a country privy or for privies where there is no regular supply of water. Before using the apparatus the recepticle or "holder" (*E*), the compartment (*B*) and the bowl (*F*), which is of peculiar construction and separated from (*B*) by a partition, are all filled with pure water. Occasionally or daily a bucket of clean water may be cast into the bowl. A strainer or perforated plate extends across the compartment (*B*) from the partition to the filter in rear of the privy. (*A*) represents the filtering or overflow compartment, showing the layers of filtering material. This arrangement can be made double, as shown in (Fig. 5), with only one "holder" and one filtering compartment for the two sides.



DOUBLE PRIVY FOR DWELLINGS OR ISOLATED BUILDINGS.

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